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A Perspective

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August 1980

EFFECTS OF WATER CONSERVATION INDUCED WASTEWATER FLOW REDUCTION

A Perspective

by

Jimmy S. Koyasako
Department of Water Resources
The Resources Agency
State of California
Sacramento, California 95814

Grant No. R806262

Project Officer

John N. English
Wastewater Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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16. ABSTRACT

This study examines the effects of indoor water conservation induced wastewater flow reduction in selected areas in California. The effects are quantified in economic terms by viewing the net economic gain to a hypothetical community which characterizes average statewide conditions. In addition, the major benefits and costs of indoor water conservation and a perspective of their relative values are presented.

Various municipal wastewater dischargers that experienced actual flow reduction during the 1976-77 drought in California provided data on the operation of their collection and treatment systems prior to, during, and after the drought. This report examines their experiences, along with other available pertinent information, to determine the advantages and disadvantages of water conservation. The results of the study quantitatively confirm the desirability of promoting water conservation and show that the benefits exceed the costs.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water conservation Water reclamation Water resources Water supply	Wastewater treatment Wastewater reuse Domestic reuse Flow reduction	13B

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is the necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research, a most vital communications link between the researcher and the user community.

This report measures the major effects of indoor water conservation and resulting wastewater flow reduction in quantified terms and gives a perspective of its relative positive and negative values. Through this study, data are being obtained to determine in a rational way measures to protect and conserve our national water resources.

Francis T. Mayo
Director
Municipal Environmental
Research Laboratory

ABSTRACT

This study examines the effects of indoor water conservation induced wastewater flow reduction in selected areas in California. The primary economic benefits and costs of water conservation to a hypothetical community which characterizes statewide conditions are quantified, and a perspective of their relative values is presented.

Various municipal wastewater dischargers that experienced actual flow reduction during the 1976-77 drought in California provided data on the operation of their collection and treatment systems prior to, during, and after the drought. This report examines their experiences, along with other available pertinent information, to determine the advantages and disadvantages of water conservation. The results of the study quantitatively confirm the desirability of promoting water conservation and show that the benefits exceed the costs.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

ac-ft	-	acre-feet
AS	-	activated sludge
ADWF	-	average dry weather flow
bbl	-	barrel
BOD	-	biochemical oxygen demand
BTU	-	British thermal unit
cm	-	centimeter
col	-	column
dam^3	-	cubic dekametre
EC	-	electrical conductivity
°F	-	Farenheit degrees
ft	-	feet
gpm or gal/min	-	gallons per minute
k	-	constant
kg	-	kilogram
kWh	-	kilowatt hour
l	-	litre
lb	-	pound
l/min	-	litres/minute
m	-	metre
m^3/s	-	cubic metres per second
mgd	-	million gallons per day
mg/l	-	milligrams per litre
mmho/cm	-	millimhos per centimetre
MUD	-	Municipal Utility District
O&M	-	operation and maintenance

LIST OF ABBREVIATIONS AND SYMBOLS (continued)

ABBREVIATIONS

psi - pounds per square inch

Q - flow

SD - Sanitary or Sanitation District

SS - suspended solids

STP - sewage treatment plant

T - temperature

TDS - total dissolved solids

SYMBOLS

$\leq$ - equal to or less than

$>$ - greater than

$\cong$ - similar to

ENGLISH TO METRIC CONVERSION FACTORS

Quantity	English Unit	Multiply By	To Get Metric Equivalent
Length	inches (in)	2.54	centimetres (cm)
	feet (ft)	0.3048	metres (m)
Volume	gallons (gal)	3.7854	litres (l)
	million gallons	3785.4	cubic metres (m^3)
	acre-feet (ac-ft)	1233.5	cubic metres (m^3)
		1.2335	cubic dekametres (dam^3)
Flow	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	million gallons per day (mgd)	0.043813	cubic metres per second (m^3/s)
		43.81250	litres per second (l/s)

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SECTION 1

INTRODUCTION

During the last 10 years, urban water conservation has attracted much attention and has widely come to be considered as an essential part of effectively managing our water resources. Urban water conservation saves water, and it also saves another precious commodity -- energy. While saving water is becoming increasingly popular across the country, perhaps the most intensive water conservation effort took place in Northern California during the acute drought of 1976-77. Although this study was not intended to investigate the effects of the drought, the drought did provide a good laboratory for measuring some of the effects of water conservation.

During the drought, Californians in many areas were encouraged by governmental and water resources management agencies to conserve water both outside and inside their homes. Some of the common practices included cutting back on or eliminating landscape irrigation, and installing low-flow faucet aerators, low-flow showerheads or flow restrictors, and "water dams" or plastic bottles in toilet tanks to reduce the amount of water used for flushing. However, these and other measures were often undertaken without a full knowledge of the positive and negative aspects of conserving water, particularly with regard to reduced wastewater flows. Questions were raised then and questions are raised now by many people who ask:

What are the effects of water conservation on wastewater collection and treatment systems?

What are the effects on wastewater reuse of any changes in the quality of the treated wastewater?

What are the positive and negative aspects of water conservation and is water conservation still worthwhile after they both have been considered?

Before we enter a new decade with an enthusiasm to promote water conservation, it is important that we find the answers to these questions, and assure ourselves that water conservation is worthy of our continued support.

The purpose of this study was to find the answers to the questions posed by assessing the effects of and estimating the long-term impact of water conservation and the resulting reduction in wastewater flow. The results of the study will help support policy and follow-up actions concerning water conservation measures and future construction of wastewater collection and treatment facilities.

When water conservation measures were undertaken during the California drought, it was anticipated that water and energy would be saved, but little was known about the effects of wastewater flow reduction on the operation and maintenance of the wastewater systems. Numerous local agencies in Northern California experienced reductions in wastewater flows during the 1976-77 drought where nearly all of the major communities were under some form of mandatory conservation.

Data were obtained from local municipal wastewater management agencies which addressed the following two questions:

1. Did reduced wastewater flows resulting from water conservation cause significant problems with regard to the operation and maintenance of sewage collection and treatment systems?

2. Were changes required in operation and maintenance procedures as a result of reduced flow effects and did the changes alter operation and maintenance (O&M) costs of the wastewater systems that could be applied to estimate future O&M costs?

The first question was answered in the negative when study results generally showed that during periods of reduced wastewater flows no serious systems operational problems were encountered. An answer to the second question was pursued by using the data collected, along with other available information, to determine how varying degrees of indoor water conservation affect wastewater handling costs. The primary economic benefits and costs of water conservation to a hypothetical community which characterizes average statewide conditions in California are quantified and gives the reader a perspective on their relative values. Because the results depict average statewide conditions, the reader should keep in mind that the effects of wastewater flow reductions can vary measurably on a case by case basis depending on the numerous variables involved.

Data were collected from local municipal wastewater agencies primarily to measure any significant effects of flow reduction on their operation and were not intended to be used for an in-depth evaluation to determine the reasons for the effects. For this reason only a limited discussion on wastewater quality and the extent of its changes and effects on the treatment plant performance during periods of flow reduction has been included in this report. Also, the reader should treat these data in the context of the purpose of the study and should not use them to help establish design or operational standards for wastewater facilities.

The future benefits and costs of indoor water conservation measures are assessed by using the next 20-year period, 1980-2000, as the basis for analysis. This time span represents a period for which expanded or new wastewater facilities would be sized for capacity. Two cases are examined as follows:

Case I - Where new wastewater facilities are additions to or expansions of existing facilities to take care of new population growth. Thus, Case I considers wastewater flows from both existing and new building constructions.

Case II - Where new wastewater facilities serve new population growth and operate independently of existing facilities. Thus, Case II considers wastewater flows from new building construction only.

SECTION 2

CONCLUSIONS

Effects on Wastewater Facilities

- One-half of the 17 wastewater systems surveyed encountered operational problems during periods of flow reductions. In general, however, the problems were not severe enough to greatly affect the systems operations. Common problems in the sewer systems were solids settling and odor. Common operational problems in the treatment plants were odor in the primary and secondary clarifiers, and bulking in secondary clarifiers due to excessive growth of filamentous bacteria.

- Remedial measures were taken to resolve the problems, and there were no documented cases where the wastewater facilities could not continue to be properly maintained.

- Changes in wastewater quality during periods of flow reduction did not generally result in more frequent treatment plant violations of biochemical oxygen demand (BOD) or suspended solids (SS) discharge requirements.

- The BOD and SS concentrations of the wastewater entering the treatment plant generally increased while the concentrations leaving the plant generally decreased during years of flow reduction. The efficiency of treatment plant removal of BOD and SS generally increased slightly.

- Energy and chemical uses were the primary items affected by wastewater flow reduction.

- The overall O&M costs for the wastewater collection system decreased slightly, with a maximum of 3% cost reduction at 50% flow reduction. Most of the reductions in cost resulted from decreased energy use for the lift pumps.

- The decrease in energy use for the treatment plants amounted to a maximum of 20% at 50% reduction in flow due to lower pumping requirements for the hydraulic load. Use of chemicals ranged from a decrease of 30% to an increase of 50%. The overall O&M costs ranged from a decrease of about 5% to an increase of about 4%. For treatment plants that experienced higher costs, increased use of chemical was the major factor.

Water Conservation Benefits and Costs

The conclusions are listed separately for the two cases analyzed.

Case I - Where the new wastewater facilities are additions to or expansions of the existing facilities to take care of new population growth. Thus, wastewater flows from both existing and new building constructions are considered.

- Indoor water use reduction for the water conservation measures examined ranged from 10% with minimal water conservation effort to a potential of 35%.
- The major benefit is energy savings due to less use of hot water in homes. Other benefits are cost savings in water supply and cost savings in municipal wastewater systems.
- More than 70% of the net benefits were attributable to water conservation measures in existing building construction.
- The optimum level of indoor water use reduction is nearly 30% and would require a strong water conservation effort.
- At the optimum level of indoor water use reduction, the benefits of water conservation are three times as great as its costs.
- Savings in capital cost of treatment plants ranged from 12% at 10% indoor use reduction to 22% at 20% to 35% indoor use reduction.
- Savings in capital cost of wastewater collection pipes of 15% would be made at all levels of indoor water use reductions.
- Savings in O&M costs of wastewater collection systems ranged from 1% at 10% reduction to 15% at 35% reduction in indoor water use.
- The annual cost of water conservation measures increased from $0.20 per household at 10% reduction in indoor use to $30 per household at 35% reduction.

Case II - Where the new wastewater facilities serve new population growth independently of existing facilities. Thus, wastewater flows from new construction only are considered.

- Indoor water use reductions for the water conservation measures examined ranged from 30% with minimal water conservation effort to a potential of 40%.
- The major benefits are energy savings due to less household use of hot water and cost savings in sewer systems. Other benefits are cost savings in water supply and wastewater treatment plants.

- Savings in capital cost of treatment plants would increase linearly to 8% at 40% reduction in indoor use.

- The average savings in capital cost of wastewater collection pipes is 7%.

- A small savings in the O&M costs of wastewater collection systems would be achieved.

- The annual cost of water conservation measures ranged from $0.10 per household at 30% reduction in indoor use to $10 per household at 40% reduction. The costs are lower than those for Case I. The reason is that water-saving toilet, shower, and faucet fixtures, which are responsible for most of the reductions, are mandatory in new construction and cost less than retrofitting existing buildings.

- The optimum level of indoor water use reduction is 37% and would require a strong water conservation effort.

- The benefits far exceed the costs.

Effects of Changes in Wastewater Effluent Quality

- The impact of increased salt concentration (as a result of flow reduction) on wastewater reuse for crop irrigation, landscape irrigation, and industrial uses has no noticeable effect on the "net benefits" (gross benefits minus costs) of water conservation. Thus, water conservation is not counterproductive to wastewater reuse.

- "Penalty costs" reduce the net benefits only slightly. Penalty costs are costs borne by consumers as a result of increased salt concentration and are associated with use of home water softeners, soap and detergent, bottled water, and water heaters.

- Desalting and blending of the effluent would mitigate any increased salt concentration. However, the cost of desalting would be considerably greater than the penalty costs.

Savings in Future Capital Expenditures for Secondary Treatment Plants

- At the optimum level of indoor water use reductions in new and existing building constructions, the expected savings in capital expenditures of secondary treatment plants proposed for new construction and enlargement in California is on the order of $210 million.

SECTION 3

RECOMMENDATIONS

It is recommended that:

- In view of its overwhelming beneficial effects, indoor water conservation measures be vigorously supported and undertaken by all interests concerned with the development and use of water. An intensive water conservation effort will be required to attain the greatest benefits over costs.

- Particular attention be given to water conservation measures in existing buildings because they are responsible for generating most of the benefits.

- The financial/social gains or losses of water conservation be investigated from different points of view in the community. When community interests find their own incentives as well as appreciate the benefits to the total community, they will be more willing to take actions leading to the development and implementation of a workable plan.

- In view of the paucity of data on wastewater effluent mineral quality, adequate information should be obtained for specific constituents affecting proposed wastewater reuse projects. The data should include, as a minimum, analyses of total dissolved solids (TDS), hardness, and boron concentrations and sodium adsorption ratios.

SECTION 4

EFFECTS OF WASTEWATER FLOW REDUCTIONS ON WASTEWATER FACILITIES

Summary

This section examines wastewater systems that actually experienced the effects of water conservation induced wastewater flow reductions. It shows that the effects did not result in any serious systems operational problems that could not be readily resolved. Although the wastewater constituents generally increased in concentrations in flows entering the treatment plants, the plants were able to operate satisfactorily. In fact the plant efficiency increased slightly.

The energy and chemical uses were the primary items affected by wastewater flow reduction. However, changes in these uses did not significantly change the overall O&M costs of the wastewater facilities. Since a definite trend of changes in O&M costs for the sewer systems developed in relation to wastewater flow reductions, these changes are used later in this report in the benefit/cost analysis.

However, changes in treatment plant O&M costs will not be applied in the benefits/costs analysis because (1) a definite relationship of changes in O&M cost with flow reductions did not develop, and (2) the changes were not significant enough to be crucial to the results of the analysis. Also included in this section are limited data on the quality of the wastewater entering and leaving the treatment plants to show plant performance during periods of flow reduction.

Study Approach

A community can reduce its residential indoor water use in many ways. Some of the common ways are use of low-flow toilet, shower, and faucet fixtures. It was understood that water and energy would be saved by these measures, but little was known about the effects of reduced wastewater flow resulting from water conservation measures on the operation and maintenance of wastewater collection and treatment facilities. For this reason, various local agencies were contacted to obtain actual data concerning:

- reduction in wastewater flow
- changes in wastewater quality

- specific operational problems encountered in collection and treatment facilities.

The agencies selected were those with systems that:

- experienced flow reduction
- had separate sanitary sewer systems rather than combined sewer systems
- had not made major modifications or expansions to its treatment plant during the period for which data was sought
- had both the collection and treatment facilities operated as a single unit as opposed to systems with multiple treatment plants where operational flexibility allowed changes in flow routes
- provided secondary treatment
- produced at least .043 m^3/s (1 mgd of wastewater).

The selection criteria were established to determine the relationship between indoor water use and wastewater flow, and to narrow the large field of wastewater facilities to survey in California. The 1976-77 drought in California created a condition requiring water conservation measures which resulted in various local wastewater management agencies experiencing reduction in wastewater flows. In general, many of these agencies were located in the San Francisco Bay area where the water shortage problem was critical. The agencies from which data on wastewater collection systems and/or treatment plants were obtained are:

- Sanitary District No. 1 of Marin County
- San Rafael Sanitary District
- Las Gallinas Valley Sanitary District
- Novato Sanitary District
- West Contra Costa Sanitary District
- East Bay Municipal Utility District - Special District No. 1
- Oro Loma Sanitary District
- Carmel Sanitary District
- City of Palo Alto
- City of Millbrae
- County of Sacramento

- City of Grass Valley

- City of Imperial Beach.

The locations of these agencies are shown on Figure 1 and their secondary treatment plants are described in Table 1.

Numerous agencies operating secondary treatment plants were contacted in Southern California where a large portion of the State's wastewater is produced. In general, it was found that wastewater flow reductions did not occur there. While the flow per capita generally lessened during the drought, the increased service connections caused the total wastewater production to either stay at the same level or increase.

Reduction in Wastewater Flow

The measurement of wastewater flow reduction was necessary because it was directly affected by the reduction in residential indoor water use. Some agencies experienced 2 years of wastewater flow reduction, in 1976 and 1977. For them, 1975, the year prior to the occurrence of flow reduction, was selected as the base year. Other agencies experienced only one year of flow reduction, in 1977. For them, 1976 was selected as the base year. The flow reductions for the various agencies are listed on Table 2. The values represent the average daily flows for the calendar year. The number of wastewater systems that experienced flow reduction, the range of flow reduction, and the average flow reduction are shown below:

	Number of Wastewater Systems with Flow Reduction	Range of Flow Reduction Change (in percent)	Average Flow Reduction Change (in percent)
First year	18	5-33	17
Second year	10	16-63	39

Las Gallinas Valley Sanitary District experienced the greatest flow reduction at 63% in 1977. It was found that flow reduction in the City of Imperial Beach was primarily attributable to the curtailment of infiltration from the high ground water table near the ocean rather than from water conservation. However, data from this city has been included because it will be applicable in assessing the energy costs of its sewer lift pumps as discussed later in this report.

Changes in Wastewater Quality

Summary

The operational parameters of BOD and SS were measured in both the influent and the effluent. The effects during flow reduction on these parameters were evaluated in terms of changes in their concentration, loading rate, and removal efficiencies. It must be emphasized that the values measured are those resulting from the total effects of flow reduction rather than just a physical reduction in the quantity of wastewater.

Other effects observed or actions taken during periods of flow reduction that contributed to change of wastewater quality include:

- Increased detention time of the waste in the sewer lines due to lower flow velocity
- Solids settling in the sewer systems due to lower flow velocity
- Addition of chemical oxidants in the sewer systems for odor control
- Additional recirculation of waste such as digester and sludge thickener supernatants to the headworks.

Influent quality data were obtained for 14 treatment plants and effluent quality for 13 plants. The changes in the quality for these plants are discussed in this section and are summarized below:

- The influent BOD and SS concentrations generally increased on the order of 15%-40%.
- The influent BOD and SS mass loading generally decreased on the order of 5%-25%.
- The effluent BOD concentration decreased in eight plants on the order of 10%-15%. It increased in three plants between 1% to 78% and did not change in two plants.
- The effluent SS concentration decreased in 10 plants on the order of 20%-30% and increased in three plants between 3%-60%.
- The percent removal of BOD and SS generally increased slightly between 1%-6%.

The increase in the influent concentrations for the two parameters (BOD and SS) was expected because of the decreased dilution of the influent caused by a reduction in flow, but one would have expected the mass loading of influent constituents to remain constant. However, the loading rate generally decreased. There is no definite answer for this occurrence, but based on interviews of local agencies and work by others (1)[1/] and (2), a combination of the following factors appears to be the likely cause:

- Increased residence time of organic wastes in the sewer systems (which probably increased biological decomposition prior to entering the treatment plant).

[1/] A numbered list of references is presented at the end of this report.

- Deposition of solids in the sewer system due to lower flow velocity.

- Hydrogen peroxide used as a chemical oxidant in some sewer systems to control odor problems may have increased biological decomposition of organic wastes.

- Less use of garbage grinders to save water.

The quality of the effluent from the treatment plants was compared with the 30-day average effluent limitations (30 mg/l concentration and 85% removal) for BOD and SS imposed on waste dischargers. The number of times the treatment plants exceeded the limitations during years of flow reduction and the number of plants exceeding the effluent limitations were examined and are summarized below:

- The number of treatment plants exceeding the effluent limitations generally decreased during years of flow reduction.

- There were generally a greater number of treatment plants with less occurrence of exceeding the limitations than those with more during years of water conservation induced flow reduction.

Treatment Plant Influent and Effluent Data

The discussion for this portion of the section deals with some specifics on the available influent and effluent quality data for the treatment plants.

The BOD influent concentration, as expected, generally increased with reductions in flow due to less dilution. As shown on Table 3, 12 plants had an increase ranging from 4% to 43% in the first year of flow reduction. One plant showed a decrease of 8% and one plant showed no change. In the second year of flow reduction, seven plants showed an increase between 4% and 82%.

In general, the SS influent concentrations also increased as shown in Table 4. In the first year of flow reduction, nine plants had an increase ranging from 4% to 42% and five plants showed a decrease between 2% and 18%. In the second year of flow reduction, five plants showed an increase between 13% and 87% while two plants showed a decrease, one 10% and the other 12%.

Contrary to expectations, influent BOD mass loading generally decreased with reduction in flow (see Table 5). The likely reasons for this decrease were stated earlier in this section. Eleven plants showed a decrease between 2% and 21% while two plants showed an increase, one with 6% and the other with 10%, during the first year of flow reduction. One plant showed no change. During the second year, six plants had a decrease between 2% and 55%, while one plant had an increase of 20%.

The SS influent mass loading also showed a general decrease as shown in Table 6. In the first year of reduction, 12 plants showed a decrease between 2% and 28% and two plants had an increase, one with 11% and the other with 22%. In the second year, six plants had a decrease between 4% and 59% while one plant had an increase of 33%.

Table 7 shows that the BOD effluent concentration generally decreased. In the first year, eight plants showed a decrease between 8% and 42%, three plants had an increase between 1% and 39%, and two plants had no change. In the second year, four plants showed a decrease between 2% and 37% while two plants showed an increase, one 46% and the other 78%.

The SS effluent concentration also generally had a decrease as shown on Table 8. In the first year, 10 plants showed a decrease between 9% and 39%, and three plants showed an increase between 3% and 60%. In the second year, four plants showed a decrease between 20% and 31% while two plants showed an increase, one 13% and the other 23%. Tables 9 and 10 show that the Percent Removal of BOD and SS generally increased slightly between 1% to 6%.

The frequency of the 30-day average effluent limitations of 30 mg/l and 85% removal for BOD and SS exceeded by the plants during years of flow reduction are shown on Table 11. It is expressed in another way as the number of plants exceeding the effluent limitations in Table 12. These tables show that during years of flow reduction (1) the number of treatment plants exceeding the limitations generally decreased, and (2) there were generally a greater number of plants with less occurrence of exceeding the limitations than those with more. Seven plants had exceeded at least one of the effluent limitations in the base year (year prior to flow reduction). During years of flow reduction, four of these plants had a decrease in the number of occurrences of exceeding the limitations and three plants had an increase.

Operational Problems Encountered in Collection and Treatment Facilities

During periods of wastewater flow reduction, problems with various systems were encountered, but none so severe as to greatly upset system operations. The only exception was at the Las Gallinas Valley S.D. treatment plant in 1976, when growth of sulfur bacteria on the rock media caused ponding in the trickling filter. This ponding and the subsequent application of chlorine to kill the sulphur bacteria upset the secondary treatment processes for several months.

Seven sewer systems and nine treatment plants experienced problems. Ten sewer systems and seven plants did not. The common problems in the sewer system and treatment plants caused by reduced wastewater flow, and actions taken by plant operators to rectify them, are tabulated below.

SEWER SYSTEMS

Problem	Action
Odor	Used chlorine or other oxidizing chemicals
Solids settling in lines	Cleaned lines more often

TREATMENT PLANTS

Problem	Action
Large grit load after first heavy rain clogged sludge draw-off line at primary clarifiers.	Dewatered clarifier and pressure-hosed off silt, or stepped up sludge draw-off rate.
Odor in primary and secondary clarifiers	Added chlorine. Recirculated primary effluent to headworks.
Odor in wet well or sludge thickener	Added chlorine
Bulking in clarifiers due to excessive filamentous bacteria growth in aeration tanks.	Added chlorine. Reduced mean cell residence time in aeration tanks.

The specific problems encountered by each agency and the actions it took to resolve the problems are shown in Tables 13 and 14. With the exception of the large grit load after the first heavy rain, the other problems encountered generally occurred during the summer months. It is not suggested that wastewater flow reduction was necessarily the sole cause of all the problems. However, the problems were those not usually encountered during normal years of rainfall and therefore it is reasoned that wastewater flow reduction was a major factor. When the remedial measures were taken, the problems were resolved and there were no documented cases where continued proper operation of the wastewater facilities could not be made. Thus, the question "Did reduced wastewater flows resulting from water conservation cause significant problems with regard to the operation and maintenance of sewage collection and treatment systems?" was answered in the negative.

A number of agencies reported that plant roots clogged their sewer lines. The drought increased the tendency of the roots to seek moisture in the sewer lines and cause clogging. This problem is attributed to the dry soil conditions caused by the drought rather than the reductions in wastewater flow due to water conservation and therefore is not included among the problems.

Changes in O&M Costs of Wastewater Collection Systems and Treatment Plants

All local agencies contacted indicated that energy and chemicals were the primary O&M cost items affected by wastewater flow reductions. The major change in energy use for the wastewater collection system was due to decreased operating time by lift station pumps. Chemical uses not governed or affected by flow, such as polymer used in sludge handling, were not included. The energy and chemical uses were identified from available data for the various agencies contacted. The amounts of these uses during years of flow reductions were identified and expressed in terms of the effect on the overall O&M costs for the individual sewer systems and treatment plants (see

Table 15). The values used to determine the proportionate cost (percent of total O&M costs) of energy and chemical uses pertained to the year as near as possible to the base year of flow. The overall O&M costs include all the variable costs of operating and maintaining the facilities, such as personnel, chemicals, utilities, materials, equipment, and administrative expenses.

The changes in the overall O&M costs for the sewer systems from Table 15 were plotted against the changes in wastewater flow reductions from Table 2 (see Figure 2). A linear regression curve for the plotted points showed that the O&M costs decreased slightly with reductions in flow. The decrease amounted to a maximum of 3% at about 50% flow reduction. As is evident in Table 15, most of the reductions in cost resulted from decreased pumping energy for the lift pumps.

A linear regression curve was also fitted to the changes in the energy use plotted against changes in flow for the treatment plants. The decrease in energy use amounted to a maximum of 20% at 50% reduction in flow due to less pumping requirements for the hydraulic load (see Figure 3).

A plot of changes in chemical use for the treatment plants showed a scattered pattern and ranged from a decrease of 30% to an increase of 120% (see Figure 4). It is reasoned that the overall chemical uses can increase or decrease depending on the operational practice during the flow reduction period. The kinds of chemicals used during flow reduction periods along with the likelihood of plus or minus changes are shown below:

Chemical Used	Purpose	Change in Quantity Used
Chlorine	Disinfection	-
Chlorine	Control of filamentous bacteria	+
Chlorine	Odor Control	+
Polymer, lime, alum, or ferric chloride	Coagulation	+
Sulfur dioxide	Dechlorination	-

The net effect of the changes in energy and chemical uses in terms of changes in the overall O&M costs of treatment plants is also shown on Table 15. These changes are plotted in Figure 5 and show a scattered pattern ranging from a decrease of about 5% to an increase of about 4%.

While substantial changes occurred in the chemical or energy uses for some systems, the overall O&M costs changed only slightly. The reason for this is that the costs of energy and chemicals were relatively small percentages of the overall O&M costs. For treatment plants that experienced increased costs, greater chemical use was the influencing factor. To illustrate these points let us examine Novato Sanitary District's Novato Plant in the second year of flow reduction as an example (see Table 15):

Change in energy use = -17.4%

Change in chemical use = +119.6%

Energy cost as % of total O&M costs = 12.3%

Chemical cost as % of total O&M costs = 2.9%

Change in O&M cost caused by change in energy use = (-17.4%) (12.3%) = -2.1%

Change in O&M costs caused by change in chemical use = (+119.6) (2.9%) = +3.5%

Net change in O&M costs = +1.4%

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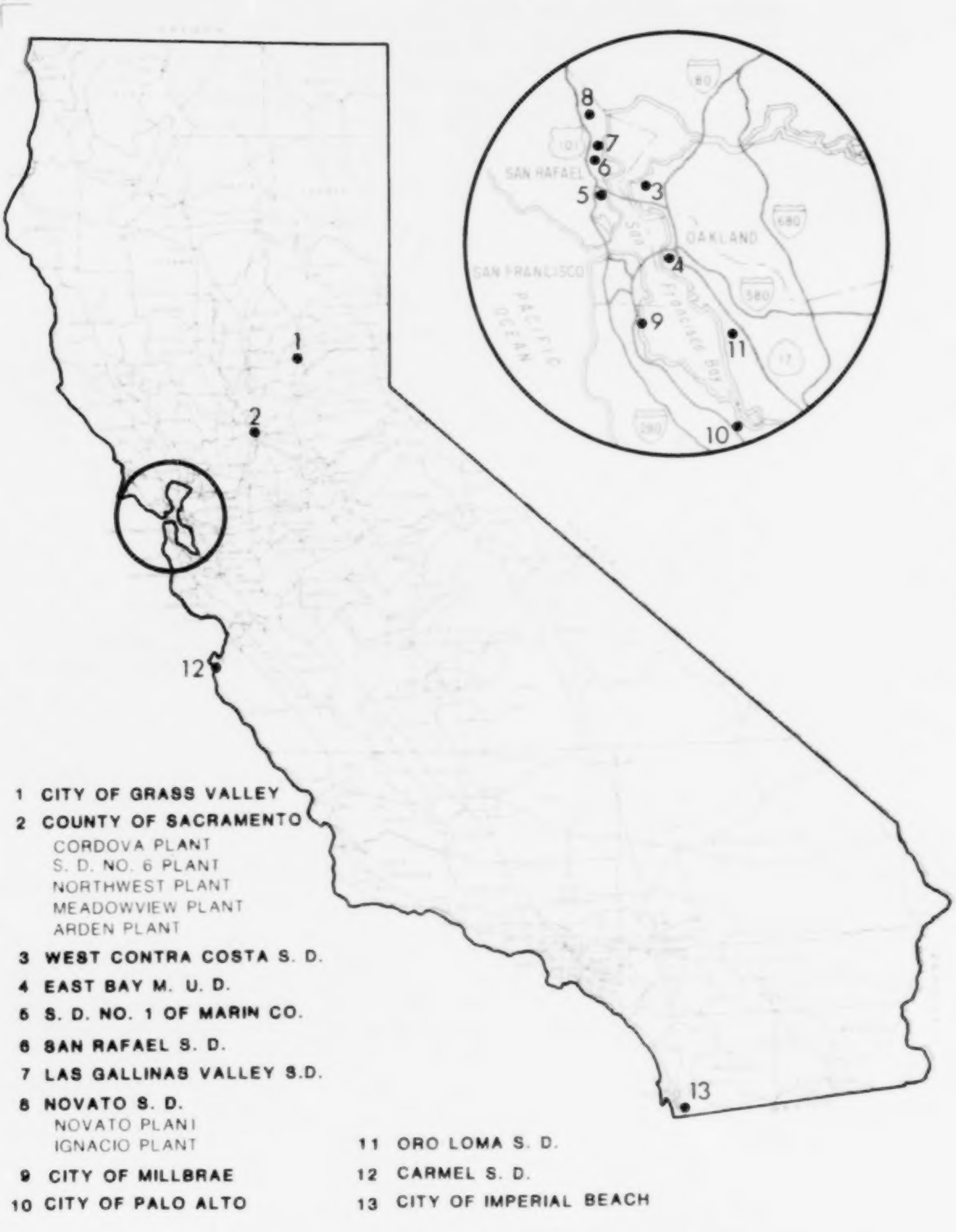
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SAN RAFAEL
OAKLAND
SAN FRANCISCO
PACIFIC OCEAN
San Francisco Bay
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280
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1 CITY OF GRASS VALLEY
2 COUNTY OF SACRAMENTO
  CORDOVA PLANT
  S. D. NO. 6 PLANT
  NORTHWEST PLANT
  MEADOWVIEW PLANT
  ARDEN PLANT
3 WEST CONTRA COSTA S. D.
4 EAST BAY M. U. D.
5 S. D. NO. 1 OF MARIN CO.
6 SAN RAFAEL S. D.
7 LAS GALLINAS VALLEY S.D.
8 NOVATO S. D.
  NOVATO PLANT
  IGNACIO PLANT
9 CITY OF MILLBRAE
10 CITY OF PALO ALTO
11 ORO LOMA S. D.
12 CARMEL S. D.
13 CITY OF IMPERIAL BEACH

Figure 1. Location of wastewater systems.

TABLE 1. DESCRIPTION OF SECONDARY TREATMENT PLANTS

Agency	Type[1/]	Design Flow m^3/s (mgd)	Description
S. D. No. 1 of Marin County	TF	0.206 (4.7)	Facilities include primary clarifiers, two-stage high rate trickling filter, secondary clarifier, microscreens, and a chlorine contact chamber. Effluent is discharged to San Francisco Bay. Sludge is removed to a sludge thickener, digester, and land disposal.
San Rafael S. D.	AS	0.219 (5.0)	Major units include a primary clarifier, activated sludge tanks, secondary clarifiers, effluent outfall line to San Pablo Bay. Outfall line is used as chlorine contact chamber. Sludge is removed to a sludge thickener, digesters, and land disposal.
Las Gallinas Valley S. D.	TF	0.131 (3.0)	Treatment plant includes primary clarifiers, trickling filters, final clarifiers, and chlorine contact pond. Effluent is discharged to Miller Creek, thence to San Pablo Bay. Sludge is removed to a sludge thickener, digesters, and land disposal.
Novato S. D. Novato Plant	AS	0.131 (3.0)	Major units include a primary clarifier, trickling filter, activated sludge tanks, secondary clarifier, and effluent polishing pond. Chlorinated effluent is discharged to San Pablo Bay. Sludge is removed to a sludge thickener, digester, and sludge drying beds.
Ignacio Plant	TF	0.088 (2.0)	Major units include primary sedimentation tanks, trickling filter, secondary sedimentation tank, and a chlorine contact pond. Effluent is discharged to San Pablo Bay. Sludge is removed to a thickener, digester, and sludge drying beds.
Carmel S. D.	AS	0.105 (2.4)	Major units include a primary sedimentation tank, activated sludge tank, and secondary tank. Chlorinated effluent is discharged to the Pacific Ocean. Sludge is removed to thickener, digester, and sludge drying beds.

[1/] AS = Activated sludge;
TF = Trickling filter.

(continued)

TABLE 1 (continued)

Agency	Type[1/]	Design Flow m^3/s (mgd)	Description
City of Millbrae	AS	0.131 (3.0)	Treatment plant includes primary sedimentation tank, activated sludge tanks, final clarifiers, and a chlorine contact tank. Effluent is discharged to San Francisco Bay. Sludge is removed to thickener, digesters, and centrifuges.
City of Grass Valley	TF	0.057 (1.3)	Treatment plant includes a primary clarifier, trickling filters, chlorine contact tank, and effluent polishing ponds. Effluent is discharged to Wolfe Creek. Sludge is removed to digesters and sludge lagoons/drying beds.
West Contra Costa S. D.	AS	0.548 (12.5)	Treatment plant includes primary sedimentation tanks, trickling filter, activated sludge tanks, secondary clarifier, and chlorine contact chamber. Effluent is discharged to San Pablo Bay. Sludge is removed to a thickener, digester, and drying beds.
Oro Loma S. D.	AS	0.876 (12.0)	Treatment plant includes a primary settling tank, activated sludge tanks, final settling tank, and a chlorination tank. Effluent is discharged to San Francisco Bay. Sludge is removed to a thickener, digester, settling tank, filter, and an incinerator.
City of Palo Alto	AS	1.533 (35.0)	Major units include primary sedimentation tanks, activated sludge tanks, final clarifiers, and chlorine contact tank. Effluent is discharged to San Francisco Bay. Sludge is removed to sludge thickeners, centrifuges, and solids incinerators.
County of Sacramento Cordova Plant	AS	0.118 (2.7)	Processes include primary sedimentation and oxidation by activated sludge. Raw primary and waste activated sludge is pumped into the county's central plant system. Chlorinated secondary effluent passes through a series of earthen ponds and is discharged to the American River.

[1/] AS = Activated sludge; TF = Trickling filter.

(continued)

TABLE 1 (continued)

Agency	Type[1/]	Design Flow m^3/s (mgd)	Description
County of Sacramento S. D. No. 6 Plant	TF	0.088 (2.0)	Features of the plant include primary clarifiers, primary and secondary trickling filters, secondary clarifiers, sludge digesters, and chlorination facilities. Sludge is exported to the county's Northeast plant. Effluent is discharged to the Sacramento River via a drainage canal.
Northeast Plant	AS	0.920 (21.0)	Unit processes include primary sedimentation, oxidation by activated sludge, anaerobic digestion, and chlorination. Effluent is discharged to the American River.
Meadowview Plant	TF	0.110 (2.5)	Processes include primary sedimentation, trickling filtration, final settling, and effluent chlorination. Sludge is pumped into the Sacramento City main system. Effluent is discharged to the Sacramento River.
Arden Plant	AS	0.438 (10.0)	Major units of the plant include activated sludge basins and secondary clarifiers. Secondary sludge is exported to the Sacramento City main plant via force main. Chlorinated effluent is discharged to the American River.

[1/] AS = Activated sludge; TF = Trickling filter.

TABLE 2. WASTEWATER FLOW

Base Year 1975

Agency (Systems with 2 years of flow reduction)	Plant Design Flow m^3/s (mgd)	Wastewater Flow m^3/s (mgd)				
		Base Year 1975	1st Year Reduction 1976	Percent Change	2nd Year Reduction 1977	Percent Change
S.D. #1 of Marin County	0.206 (4.7)	0.276 (6.3)	0.184 (4.2)	-33	0.131 (3.0)	-52
San Rafael S.D.	0.219 (5.0)	0.180 (4.10)	0.155 (3.53)	-14	0.092 (2.11)	-49
Las Gallinas Valley S.D.	0.131 (3.0)	0.109 (2.48)	0.086 (1.97)	-21	0.040 (0.91)	-63
Novato S.D. Novato Plant	0.131 (3.0)	0.127 (2.90)	0.111 (2.54)	-12	0.084 (1.91)	-34
Novato S.D. Ignacio Plant	0.088 (2.0)	0.052 (1.18)	0.046 (1.04)	-12	0.034 (0.78)	-34
East Bay M.U.D. S.D. #1	Sewer System Only	3.360 (76.6)	3.019 (68.9)	-10	2.751 (62.8)	-18
Carmel S.D.	0.105 (2.4)	0.092 (2.09)	0.087 (1.98)	-5	0.047 (1.08)	-48
City of Millbrae	0.131 (3.0)	0.096 (2.25)	0.084 (1.91)	-15	0.071 (1.61)	-28
County of Sacramento Arden Plant	0.438 (10.0)	0.267 (6.1)	0.250 (5.7)	-7	0.215 (4.9)	-16
City of Grass Valley	0.057 (1.3)	0.067 (1.53)	0.043 (0.99)	-35	0.036 (0.83)	-46

(continued)

TABLE 2 (continued)

Base Year 1976

Agency (Systems with 2 years of flow reduction)	Plant Design Flow m^3/s (mgd)	Wastewater Flow m^3/s (mgd)				
		Base Year 1976	1st Year Reduction 1977	Percent Change	2nd Year Reduction 1977	Percent Change
West Contra Costa S.D.	0.548 (12.5)	0.311 (7.1)	0.228 (5.2)	-27		--
Oro Loma S.D.	0.876 (20.0)	0.556 (12.7)	0.394 (9.0)	-29	No Second Year Flow Reduction	--
City of Palo Alto	1.533 (35.0)	1.244 (28.4)	0.986 (22.5)	-21		--
County of Sacramento						
Cordova Plant	0.118 (2.7)	0.097 (2.21)	0.077 (1.75)	-21		--
S.D. #6 Plant	0.088 (2.0)	0.087 (2.0)	0.079 (1.8)	-10		--
Northeast Plant	0.920 (21.0)	0.835 (19.06)	0.691 (15.78)	-17		--
Meadowview Plant	0.110 (2.5)	0.059 (1.35)	0.050 (1.15)	-15		--
City of Imperial Beach	Sewer System Only	0.092 (2.11)	0.084 (1.91)	-10		--
Average				-17		-39

TABLE 3. INFLUENT BIOCHEMICAL OXYGEN DEMAND (BOD) CONCENTRATION[1]
(in mg/1)

Treatment Plants		Base Year 1975	1st Year Flow Reduction 1976	Percent Change	2nd Year Flow Reduction 1977	Percent Change
San Rafael S.D.	Plants with two years of flow reduction	206	234	+14	375	+82
Las Gallinas Valley S.D.		218	219	0	319	+46
Novato S.D.						
Novato Plant		237	246	+4	246	+4
Ignacio Plant		219	233	+6	268	+22
East Bay MUD, S.D.#1		300	349	+16	433	+44
Carmel S.D.		213	237	+11	331	+44
County of Sacramento Arden Plant		164	187	+14	220	+34
		Base Year 1976	1st Year Flow Reduction 1977	Percent Change		
West Contra Costa S.D.	Plants with one yr. of flow reduction	226	302	+34		
Oro Loma S.D.		188	248	+32		
City of Palo Alto		149	177	+19		
County of Sacramento						
Cordova Plant		291	418	+43	No second year Flow Reduction	
S.D. #6 Plant		256	235	-8		
Northeast Plant		175	223	+27		
Meadowview Plant		199	213	+7		

1/ Average Annual Values

TABLE 4. INFLUENT SUSPENDED SOLIDS (SS) CONCENTRATION1/ (in mg/1)

Treatment Plants		Base Year 1975	1st Year Flow Reduction 1976	Percent Change	2nd Year Flow Reduction 1977	Percent Change
San Rafael S.D.	Plants with two years of flow reduction	278	394	+42	521	+87
Las Gallinas Valley S.D.		224	219	-2	253	+13
Novato S.D.						
Novato Plant		387	404	+4	340	-12
Ignacio Plant		375	404	+16	337	-10
East Bay MUD, S.D. #1		241	228	-5	384	+59
Carmel S.D.		283	265	-6	344	+22
County of Sacramento Arden Plant		164	207	+26	193	+18
		Base Year 1976	1st Year Flow Reduction 1977	Percent Change		
West Contra Costa S.D.	Plants with one yr. of flow reduction	196	260	+33	No Second Year Flow Reduction	
Oro Loma S.D.		290	339	+17		
City of Palo Alto		181	213	+18		
County of Sacramento						
Cordova Plant		501	635	+26		
S.D. #6 Plant		379	311	-18		
Northeast Plant		180	189	+5		
Meadowview Plant		183	192	+5		

1/ Average Annual Values

TABLE 5. INFLUENT BOD LOAD[1/] (in kg/day/capita)

Treatment Plants		Base Year 1975	1st Year Flow Reduction 1976	Percent Change	2nd Year Flow Reduction 1977	Percent Change
San Rafael S.D.	Plants with two years of flow reduction	.107	.104	-3	.100	-7
Las Gallinas Valley S.D.		.073	.058	-21	.033	-55
No[illegible]o S.D.						
Novato Plant		.088	.076	-14	.056	-36
Ignacio Plant		.062	.056	-10	.046	-26
East Bay MUD, S.D. #1		.149	.158	+6	.179	+20
Carmel S.D.		.120	.118	-2	.087	-28
County of Sacramento Arden Plant		.083	.083	0	.081	-2
		Base Year 1976	1st Year Flow Reduction 1977	Percent Change		
West Contra Costa S.D.	Plants with one yr. of flow Reduction	.083	.080	-4	No Second Year Flow Reduction	
Oro Loma S.D.		.065	.060	-8		
City of Palo Alto		.088	.081	-8		
County of Sacramento						
Cordova Plant		.101	.111	+10		
S.D. #6 Plant		.064	.051	-20		
Northeast Plant		.079	.076	-4		
Meadowview Plant		.072	.064	-11		

1/ Average Annual Values

TABLE 6. INFLUENT SUSPENDED SOLIDS (SS) LOAD 1/ (in kg/day/capita)

Treatment Plants		Base Year 1975	1st Year Flow Reduction 1976	Percent Change	2nd Year Flow Reduction 1977	Percent Change
San Rafael S.D.	Plants with two years of flow reduction.	.144	.176	+22	.139	-4
Las Gallinas Valley S.D.		.075	.058	-23	.031	-59
Novato S.D.						
Novato Plant		.143	.125	-13	.077	-46
Ignacio Plant		.106	.076	-28	.057	-46
East Bay MUD, S.D. #1		.120	.103	-14	.159	+33
Carmel S.D.		.154	.132	-14	.091	-59
County of Sacramento Arden Plant		.083	.092	+11	.071	-15
		Base Year 1976	1st Year Flow Reduction 1977	Percent Change		
West Contra Costa S.D.	Plants with one year of flow Reduction.	.072	.069	-4		
Oro Loma S.D.		.100	.082	-18		
City of Palo Alto		.107	.097	-9		
County of Sacramento						
Cordova Plant		.173	.169	-2	No Second Year Flow Reduction	
S.D. #6 Plant		.095	.068	-28		
Northeast Plant		.082	.065	-21		
Meadowview Plant		.066	.057	-14		

1/ Average Annual Values

TABLE 7. EFFLUENT BOD CONCENTRATION 1/ (in mg/1)

Treatment Plants		Base Year 1975	1st Year Flow Reduction 1976	Percent Change	2nd Year Flow Reduction 1977	Percent Change
San Rafael S.D.	Plants with two years of flow reduction	19.0	11.0	-42	12.0	-37
Las Gallinas Valley S.D.		27.3	31.5	+15	26.7	-2
Novato S.D.						
Novato Plant		15.1	13.9	-8	22.0	+46
Ignacio Plant		15.2	12.9	-15	13.1	-14
Carmel S.D.		18	25	+39	32	+78
County of Sacramento Arden Plant		7.2	6.0	-17	6.7	-7
		Base Year 1976	1st Year Flow Reduction 1977	Percent Change		
West Contra Costa S.D.	Plants with one yr. of flow reduction	4	4	0	No Second Year Flow Reduction	
Oro Loma S.D.		4	4	0		
City of Palo Alto		11.4	10.1	-11		
County of Sacramento						
Cordova Plant		8.2	8.3	+1		
S.D. #6 Plant		15.9	13.8	-13		
Northeast Plant		13.6	11.3	-17		
Meadowview Plant		19.4	16.9	-13		

1/ Average Annual Values

TABLE 8. EFFLUENT SS CONCENTRATION 1/ (in mg/1)

Treatment Plants		Base Year 1975	1st Year Flow Reduction 1976	Percent Change	2nd Year Flow Reduction 1977	Percent Change
San Rafael S.D.	Plants with two years of flow reduction	26.0	16.0	-39	18.0	-31
Las Gallinas Valley S.D.		28.6	26.0	-9	22.9	-20
Novato S.D.						
Novato Plant		19.7	15.2	-23	22.2	+13
Ignacio Plant		21.9	17.0	-22	15.2	-31
Carmel S.D.		22	18	-18	27	+23
County of Sacramento Arden Plant		9.3	11.3	+22	7.3	-22
		Base Year 1976	1st Year Flow Reduction 1977	Percent Change		
West Contra Costa S.D.	Plant with one year of flow reduction	5	8	+60	No Second Year Flow Reduction	
Oro Loma S.D.		27	19	-30		
City of Palo Alto		17.6	12.4	-30		
County of Sacramento						
Cordova Plant		8.5	5.9	-31		
S.D. #6 Plant		20.5	16.1	-22		
Northeast Plant		11.3	8.3	-27		
Meadowview Plant		26.4	27.3	+ 3		

1/ Average Annual Values

TABLE 9. PERCENT REMOVAL OF BOD LOAD[1]

Treatment Plants		Base Year 1975	1st Year Flow Reduction 1976	Percent Change	2nd Year Flow Reduction 1977	Percent Change
San Rafael S.D.	Plants with two years of flow reduction	91	95	+4	97	+6
Las Gallinas Valley S.D.		88	86	-2	92	+5
Novato S.D.						
Novato Plant		94	94	0	91	-3
Ignacio Plant		93	94	+1	95	+2
Carmel S.D.		92	89	-3	90	-2
County of Sacramento Arden Plant		96	97	+1	97	+1
		Base Year 1976	1st Year Flow Reduction 1977	Percent Change		
West Contra Costa S.D.	Plants with one year of flow reduction	98	99	+1		
Oro Loma S.D.		89	90	+1		
City of Palo Alto		93	94	+1		
County of Sacramento						
Cordova Plant		97	98	+1	No Second Year Flow Reduction	
S.D. #6 Plant		94	94	0		
Northeast Plant		92	95	+3		
Meadowview Plant		90	92	+2		

[1] Average Annual Values

TABLE 10. PERCENT REMOVAL OF SS LOAD[1/]

Treatment Plants		Base Year 1975	1st Year Flow Reduction 1976	Percent Change	2nd Year Flow Reduction 1977	Percent Change
San Rafael S.D.	Plants with two years of flow reduction	91	96	+5	97	+6
Las Gallinas Valley S.D.		87	88	+1	91	+5
Novato S.D.						
Novato Plant		95	96	+1	94	-1
Ignacio Plant		93	94	+1	95	+2
Carmel S.D.		92	93	+1	92	0
County of Sacramento Arden Plant		95	95	0	96	+1
		Base Year 1976	1st Year Flow Reduction 1977	Percent Change		
West Contra Costa S.D.	Plants with one year of flow reduction	97	97	0	No Second Year Flow Reduction	
Oro Loma S.D.		91	94	+3		
City of Palo Alto		90	94	+4		
County of Sacramento						
Cordova Plant		98	99	+1		
S.D. #6 Plant		94	95	+1		
Northeast Plant		94	96	+2		
Meadowview Plant		86	86	0		

1/ Average Annual Values

TABLE 11. NUMBER OF TIMES TREATMENT PLANTS EXCEEDED 30-DAY AVERAGE EFFLUENT LIMITATIONS

Base Year is 1975

Treatment Plants		Biochemical Oxygen Demand (BOD)						Suspended Solids (SS)					
		Base Year		1st Year Flow Reduction		2nd Year Flow Reduction		Base Year		1st Year Flow Reduction		2nd Year Flow Reduction	
Effluent Limitations		30 mg/1	85% Removal	30 mg/1	85% Removal	30 mg/1	85% Removal	30 mg/1	85% Removal	30 mg/1	85% Removal	30 mg/1	85% Removal
San Rafael S.D.	Plants with 2 years of Flow Reduction	3	2	0	0	0	0	3	2	1	0	1	0
Las Gallinas Valley S.D.		2	1	6	6	4	0	3	1	4	3	3	0
Novato S.D.													
Novato Plant		1	2	0	0	0	0	2	2	0	0	0	0
Ignacio Plant		0	0	0	0	0	0	2	0	1	0	0	0
Carmel S.D.		0	0	4	2	5	1	2	1	2	1	4	1
County of Sacramento													
Arden Plant		0	0	0	0	0	0	0	0	0	1	0	0
Central Plant		0	0	0	0	0	0	0	0	0	0	0	0
Base Year is 1976													
West Contra Costa S.D.	Plants with 1 year of Flow Reduction	0	0	0	0	NA	NA	0	0	0	0	NA	NA
Oro Loma S.D.		0	1	1	0	NA	NA	3	1	0	0	NA	NA
City of Palo Alto		0	0	0	0	NA	NA	0	0	0	0	NA	NA
County of Sacramento													
Cordova Plant		0	0	0	0	NA	NA	0	0	0	0	NA	NA
S.D. #6 Plant		0	0	0	0	NA	NA	0	0	0	0	NA	NA
Northeast Plant		0	0	0	0	NA	NA	0	0	0	0	NA	NA
Meadowview Plant		0	0	0	0	NA	NA	1	1	0	4	NA	NA

NOTE: NA = Not Applicable

TABLE 12. NUMBER OF TREATMENT PLANTS EXCEEDING 30-DAY AVERAGE EFFLUENT LIMITATIONS

Treatment Plants		Biochemical Oxygen Demand (BOD)						Suspended Solids (SS)					
		30 mg/l Limit			85% Removal			30 mg/l Limit			85% Removal		
		Base Year	1st Year of Flow Reduction	2nd Year of Flow Reduction	Base Year	1st Year of Flow Reduction	2nd Year of Flow Reduction	Base Year	1st Year of Flow Reduction	2nd Year of Flow Reduction	Base Year	1st Year of Flow Reduction	2nd Year of Flow Reduction
With violations	Plants with 2 years of flow reduction	3	2	2	3	3	2	5	4	3	4	3	1
With no violations		4	5	5	4	4	5	2	3	4	3	4	6
With more violations during yrs of flow reduction		NA	2	2	NA	2	1	NA	1	1	NA	2	0
With fewer violations during yrs of flow reduction		NA	2	2	NA	2	3	NA	3	3	NA	2	3
With violations	Plants with 1 year of flow reduction	0	1	NA	1	0	NA	2	0	NA	2	1	NA
With no violations		7	6	NA	6	7	NA	5	7	NA	5	6	NA
With more violations during yrs of flow reduction		NA	1	NA	NA	0	NA	NA	0	NA	NA	1	NA
With fewer violations during yrs of flow reduction		NA	0	NA	NA	1	NA	NA	1	NA	NA	1	NA

NOTE: NA = Not Applicable

TABLE 13. PROBLEMS IN SEWER SYSTEMS DURING PERIODS OF REDUCED WASTEWATER FLOW

Agency	Problem	Action Taken
S.D. #1 of Marin County	Slight Odor	Applied hydrogen peroxide at lift stations
San Rafael S.D.	Odor	Applied hydrogen peroxide at lift stations
Las Gallinas Valley S.D.	Odor	Applied chlorine dioxide
East Bay MUD S.D. #1	Odor	Applied more sodium hypochlorite than usual
City of Millbrae	Solids settling	Hauled water with tank truck and flushed lines
Carmel S.D.	Solids settling	Cleaned lines more often
City of Grass Valley	Solids settling	Cleaned lines more often
Novato S.D.		
Ignacio System	None	
Novato System	None	
West Contra Costa S.D.	None	
Oro Loma S.D.	None	
City of Palo Alto	None	
County of Sacramento		
Cordova System	None	
S.D. #6 System	None	
Northeast System	None	
Arden System	None	
Meadowview System	None	

TABLE 14. PROBLEMS IN TREATMENT PLANTS DURING PERIODS OF REDUCED WASTEWATER FLOW

Agency	Problem	Action
S.D. #1 of Marin County	Slight odor problem at sludge thickener.	Added chlorine to return sludge line.
San Rafael S.D.	Odor	Added hydrogen peroxide and more chlorine at primary clarifier.
Las Gallinas Valley S.D.	Large load of grit after first heavy rainfall.	Removed grit.
	Sludge draw-off at primary clarifiers clogged due to excessive grit.	Stepped up pumping time.
	Sulfur bacteria grew on rock media and clogged and ponded trickling filter. Sulfur also caused odor.	Added chlorine to kill sulfur bacteria.
	Ponding of biofilter caused efficiency of final clarifier to go down.	Added alum to increase clarifier efficiency.
	Septic influent caused sludge thickener to receive septic sludge.	Added more chlorine at sludge thickener.
City of Millbrae	Odor in wet well.	Prechlorination.
	Bulking in clarifiers due to excessive growth of filamentous bacteria.	Used more coagulants. Used more postchlorination. Recycled water from clarifiers to headworks. Changed mean cell residence time in aeration tanks.

(continued)

TABLE 14 (continued)

Agency	Problem	Action
Carmel S.D.	More filamentous bacteria growth than usual in aeration tanks.	Chlorinated return activated sludge and reduced mean cell residence time.
Novato S.D.		
Ignacio Plant	None	
Novato Plant	Odor in primary and secondary clarifiers.	Prechlorination. Recirculated primary effluent to headworks.
West Contra Costa S.D.	Large grit load after first heavy rain clogged sludge lines and clarifier mechanisms. Could not maintain good control with instrumentation at low flows.	Dewatered clarifier and pressure-hosed off the silt. Instruments for chlorination, dechlorination, and pH controls set at minimum values which caused over-application.
City of Palo Alto	Slight bulking of secondary clarifier caused by filamentous bacteria.	Chlorinated return activated sludge.
Oro Loma S.D.	None	
City of Grass Valley	None	
Sacramento County		
Cordova Plant	None	
S.D. #6 Plant	None	
Northeast Plant	None	
Arden Plant	None	
Meadowview Plant	None	

TABLE 15. CHANGES TO ITEMS AFFECTED BY FLOW REDUCTIONS AND THEIR EFFECT ON TOTAL O & M COST

1	2	3	4	5	6	7	8	9	10	11	12
Agency	System	Power/ Cost in Percent of Total O&M Cost	Chemical Cost in Percent of Total O&M Cost	Year 1/ of Wastewater Flow Reduction	Power Use		Chemical Use		Change in Total O&M Cost (percent)		
					kWh	Percent Change	Tonne (tons)	Percent Change	Due to Power Use Col.3 x Col.7	Due to Chemical Use Col.4 x Col.9	Total Col.10 + Col.11
S.D. #1 of Marin County	Sewer	8.5	0.2	Base	620,600	--	0.9 (1.0)	--	--	--	--
				First	483,000	-22.2	4.5 (5.0)	+400	-1.9	+0.8	-1.1
				Second	343,100	-44.7	4.8 (5.3)	+430	-3.8	+0.9	-2.9
Novato S.D.	Sewer	7.2	0	Base	190,500	--	0	NA	--	NA	--
				First	170,300	-10.6	0	NA	-0.7	NA	-0.7
				Second	150,600	-21.0	0	NA	-1.5	NA	-1.5
City of Millbrae	Sewer	3.3	0	Base	27,600	--	0	NA	--	NA	--
				First	26,900	- 2.7	0	NA	-0.1	NA	-0.1
				Second	19,400	-29.8	0	NA	-1.0	NA	-1.0
Carmel S.D.	Sewer	5.5	0	Base	241,000	--	0	NA	--	NA	--
				First	203,500	-15.6	0	NA	-0.9	NA	-0.9
				Second	133,100	-44.8	0	NA	-2.5	NA	-2.5

1/ Base year is 1975 where agencies experienced 2 years of wastewater flow reduction.
Base year is 1976 where only 1 year of flow reduction was experienced.

(continued)

TABLE 15 (continued)

1	2	3	4	5	6	7	8	9	10	11	12
Agency	System	Power/ Cost in Percent of Total O&M Cost	Chemical Cost in Percent of Total O&M Cost	Year[1/] of Waste-water Flow Reduc-tion	Power Use		Chemical Use		Change in Total O&M Cost (percent)		
					kWh	Percent Change	Tonne (tons)	Percent Change	Due to Power Use Col. 3 x Col. 7	Due to Chemi-cal Use Col. 4 x Col. 9	Total Col.10 + Col.11
County of Sacramento	Arden Sewer	1.2	0	Base	239,700	--	0	NA	--	NA	--
				First	240,700	+ 0.4	0	NA	0	NA	0
				Second	193,400	-19.3	0	NA	-0.2	NA	-0.2
Oro Loma S.D.	Sewer	2.0	0	Base	122,300	--	0	NA	--	NA	--
				First	80,300	-34.4	0	NA	0.7	NA	0.7
County of Sacramento	S.D. #6 Sewer	2.2	1.3	Base	241,300	--	10.0 (11.0)	--	--	--	--
				First	202,100	-16.2	2.7 (3.0)	-72.7	-0.4	-0.9	-1.3
	North-east Sewer	1.5	2.4	Base	908,400	--	144 (159)	--	--	--	--
				First	870,700	-4.2	123 (136)	-14.5	-0.1	-0.3	-0.4

1/ Base year is 1975 where agencies experienced 2 years of wastewater flow reduction.
Base year is 1976 where only 1 year of flow reduction was experienced.

(continued)

TABLE 15 (continued)

1	2	3	4	5	6	7	8	9	10	11	12
Agency	System	Power/ Cost in Percent of Total O&M Cost	Chemical Cost in Percent of Total O&M Cost	Year[1/] of Wastewater Flow Reduction	Power Use		Chemical Use		Change in Total O&M Cost (percent)		
					kWh	Percent Change	Tonne (tons)	Percent Change	Due to Power Use Col.3 x Col.7	Due to Chemical Use Col.4 x Col.9	Total Col.10 + Col.11
City of Imperial Beach	Sewer	6.7	0	Base	22,300[2/]	--	0	NA	--	NA	--
				First	21,200[2/]	-5.3	0	NA	-0.4	NA	0.4
Novato S.D.	Novato Treatment Plant	12.3	2.9	Base	2,107,800	--	37.6 (41.5)	--	--	--	--
				First	1,838,700	-12.8	42.8 (47.2)	+13.9	-1.6	+0.4	-1.2
				Second	1,741,600	-17.4	82.6 (91.0)	+119.6	-2.1	+3.5	+1.4
	Ignacio Treatment Plant	9.6	3.6	Base	28,100[2/]	--	12.6 (13.9)	--	--	--	--
				First	24,600[2/]	-12.2	15.2 (16.8)	+21.4	-1.2	+0.8	-0.4
				Second	23,000[2/]	-18.1	16.2 (17.9)	+28.9	-1.7	+1.0	-0.7

1/ Base year is 1975 where agencies experienced 2 years of wastewater flow reduction. Base year is 1976 where only 1 year of flow reduction was experienced.

2/ Value is monthly average.

(continued)

TABLE 15 (continued)

1	2	3	4	5	6	7	8	9	10	11	12
Agency	System	Power/ Cost in Percent of Total O&M Cost	Chemical Cost in Percent of Total O&M Cost	Year 1/ of Wastewater Flow Reduction	Power Use		Chemical Use		Change in Total O&M Cost (percent)		
					kWh	Percent Change	Tonne (tons)	Percent Change	Due to Power Use Col.3 x Col.7	Due to Chemical Use Col.4 x Col.9	Total Col.10 + Col.11
Carmel S.D.	Treatment Plant	9.2	1.9	Base	1,365,467	--	12.9 (14.2)	--	--	--	--
				First	1,229,120	-10.0	19.1 (21.1)	+48.4	-0.9	+0.9	0
				Second	1,024,960	-24.9	15.8 (17.4)	+22.8	-2.3	+0.4	-1.9
County of Sacramento	Arden Treatment Plant	8.1	12.7	Base	4,592,900	--	163 (180)	--	--	--	--
				First	4,385,600	-4.5	174 (192)	+4.4	-0.4	+0.6	+0.2
				Second	4,315,200	-6.0	220 (243)	+35.0	-0.5	+4.4	+3.9

1/ Base year is 1975 where agencies experienced 2 years of wastewater flow reduction.
Base year is 1976 where only 1 year of flow reduction was experienced.

(continued)

TABLE 15 (continued)

1	2	3	4	5	6	7	8	9	10	11	12
Agency	System	Power/ Cost in Percent of Total O&M Cost	Chemical Cost in Percent of Total O&M Cost	Year[1/] of Wastewater Flow Reduction	Power Use		Chemical Use		Change in Total O&M Cost (percent)		
					kWh	Percent Change	Tonne (tons)	Percent Change	Due to Power Use Col.3 x Col.7	Due to Chemical Use Col.4 x Col.9	Total Col.10 + Col.11
West Contra Costa S.D.	Treatment Plant	16.1	9.8	Base	6,512,600	--	492.2 (473.1)	--	--	--	--
				First	5,950,400	-8.6	463.7 (511.1)	+8.0	-1.4	+0.8	-0.6
Oro Loma S.D.	Treatment Plant	13.9	4.5	Base	5,685,900	--	215.5 (237.5)	--	--	--	--
				First	5,106,400	-10.2	164.1 (180.9)	-23.8	-1.4	-1.1	-2.5
City of Palo Alto	Treatment Plant	11.7	12.5	Base	12,171,000	--	425.2 (468.7)	--	--	--	--
				First	12,432,000	+2.1	531.4 (585.8)	+25.0	+0.2	+3.1	+3.3

[1/] Base year is 1975 where agencies experienced 2 years of wastewater flow reduction. Base year is 1976 where only 1 year of flow reduction was experienced.

(continued)

TABLE 15 (continued)

1	2	3	4	5	6	7	8	9	10	11	12
Agency	System	Power/ Cost in Percent of Total O&M Cost	Chemical Cost in Percent of Total O&M Cost	Year[1/] of Waste-water Flow Reduction	Power Use		Chemical Use		Change in Total O&M Cost (percent)		
					kWh	Percent Change	Tonne (tons)	Percent Change	Due to Power Use Col.3 x Col.7	Due to Chemical Use Col.4 x Col.9	Total Col.10 + Col.11
County of Sacramento	S.D.#6 Treatment Plant	8.3	17.7	Base	850,000	--	73 (80)	--	--	--	--
				First	853,300	+0.4	53 (58)	-27.5	0	-4.9	-4.9
	Northeast Treatment Plant	2.3	20.8	Base	2,368,800	--	762 (840)	--	--	--	--
				First	2,204,600	-6.9	757 (835)	-0.6	-0.2	-0.1	-0.3

[1/] Base year is 1975 where agencies experienced 2 years of wastewater flow reduction.
Base year is 1976 where only 1 year of flow reduction was experienced.

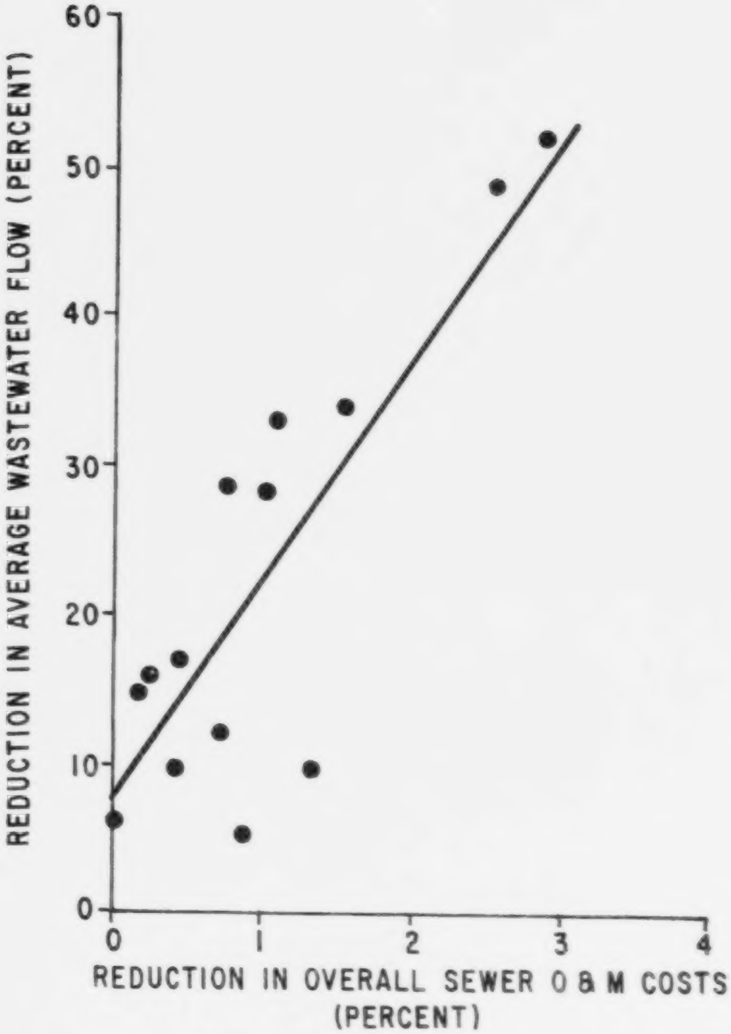

Figure 2. Reduction in sewer operation and maintenance (O & M) costs.

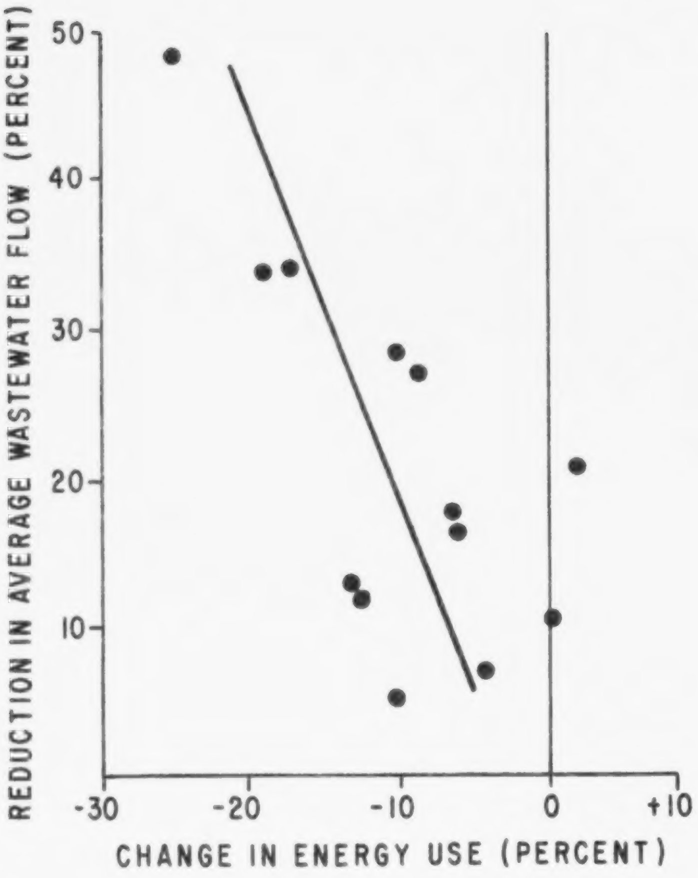

Figure 3. Change in secondary treatment plant energy use.

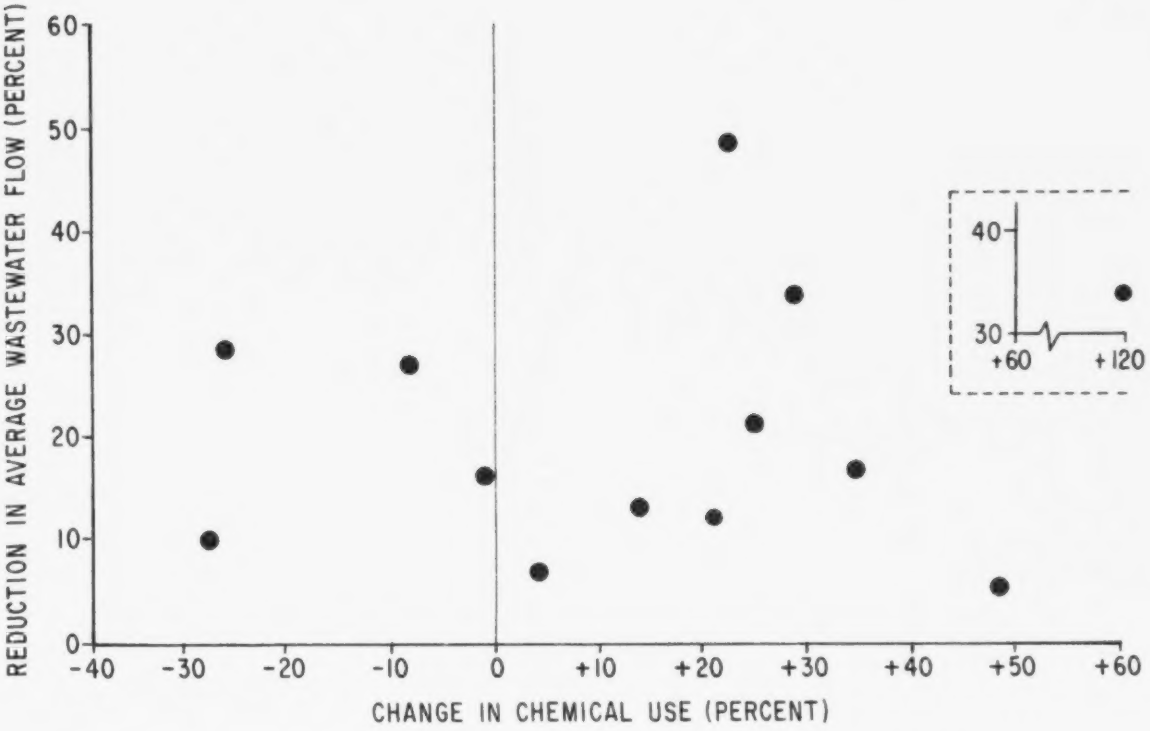

Figure 4. Change in secondary treatment plant chemical uses.

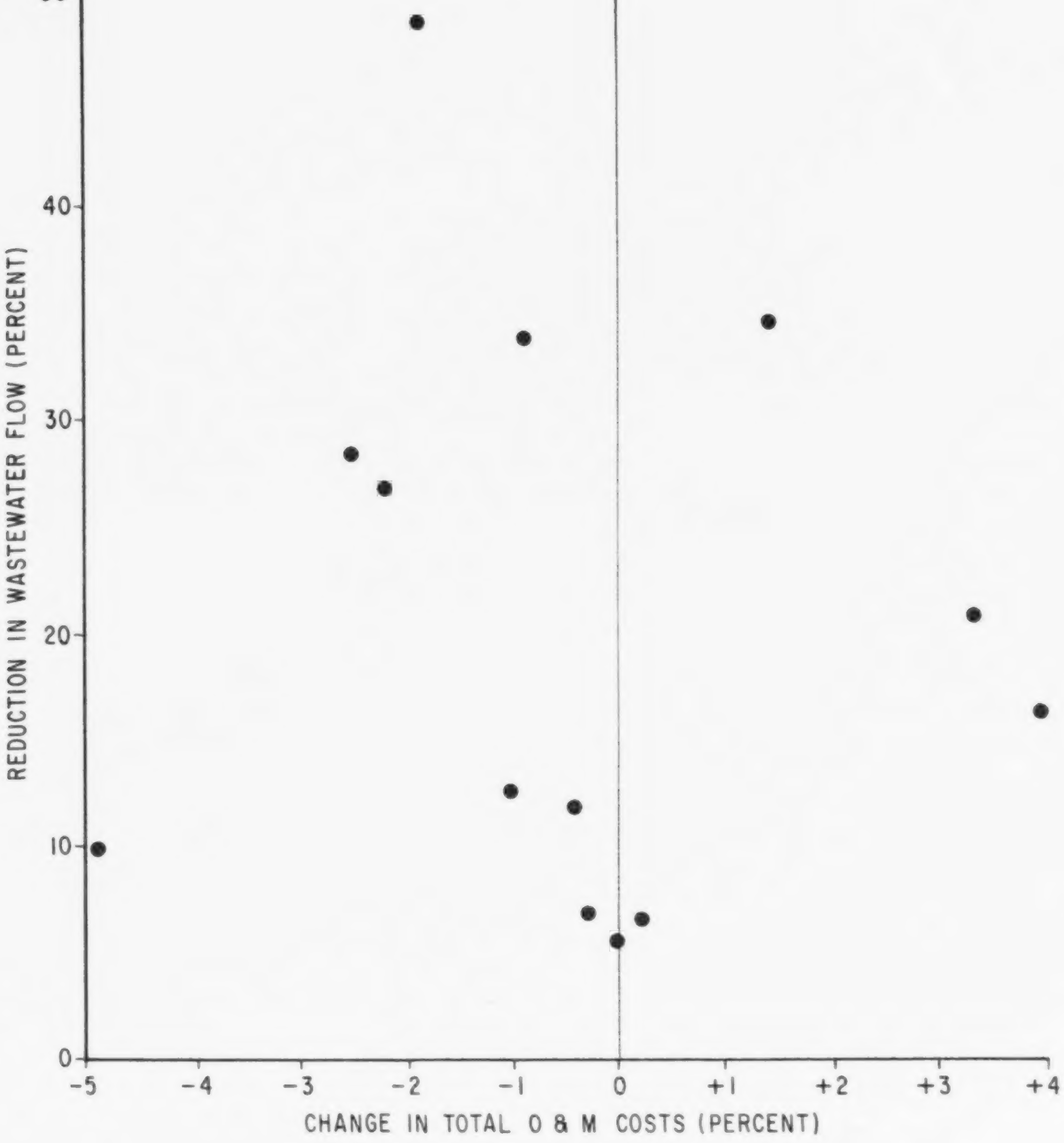

Figure 5. Change in operation and maintenance costs of secondary treatment plants.

SECTION 5

WATER CONSERVATION BENEFITS

In order to answer the question "Is conservation of indoor water use worthwhile?", the positive and negative effects of indoor water conservation, i.e., its primary benefits and primary costs, must be analyzed in perspective. This can be done by choosing conditions for analysis to represent what could be expected in the future on a statewide basis if indoor water conservation measures were taken. One of the major items in this analysis is to estimate the primary benefits of water conservation.

Benefits resulting from savings in water, energy, and wastewater facilities costs will be examined in this section. The approach used to make the benefits analysis are as follows:

- Select conditions for analysis. This involves choosing a period of analysis and two cases for which new sewer systems and secondary treatment plants are commonly constructed to serve new population growth.

- Identify how indoor water use can be reduced. Various scenarios of water conservation measures are examined to determine the amounts of indoor water use reduction at different levels of water conservation efforts ranging from minimal to potential.

- Establish the relationship among indoor water use reduction, design, flow, average flow, and average dry weather flow (ADWF). This is necessary so that the indoor water use (assumed as being similar to the ADWP) can be expressed in terms of design flow and average flow. Design and average flows are used to estimate cost savings (benefits) in the wastewater facilities due to wastewater flow reductions.

- Select levels of indoor water use reduction and sizes of wastewater collection and treatment systems. Benefits are analyzed for small, medium, and large systems at different levels of indoor water use reduction.

- Determine amount of water savings. This is done by applying the selected levels of indoor water use reductions to the wastewater systems.

- Determine amount of water supply benefits. The amount of water saved is treated as the amount of water that does not need to be supplied in the future. The cost of supplying that water which otherwise would most likely be incurred in the absence of water savings is used as a measure of water supply benefits.

- Determine energy benefits. Two types of energy savings are considered. One is the savings due to less use of hot water and the other is the savings that results because less water needs to be treated and conveyed in the local water supply distribution systems.

- Determine cost savings (benefits) in wastewater collection and treatment systems. The extent to which future construction of these systems can be sized smaller and construction costs saved as well as savings in the operation and maintenance cost due to reductions in wastewater flow are examined.

- Determine total benefits. This is the total of all the benefits described above. The benefits are measured in terms of annual equivalent benefits. For brevity, they will be referred to as "annual benefits" hereafter. An interest rate of 7% and a service life of 25 years for secondary treatment plants and 50 years for sewer systems are used (3).

A 20-year period of analysis, from 1980 to 2000, was selected to assess the benefits and costs of indoor water conservation. It also represents the period for which new wastewater facilities are being constructed to serve new growth and sized for capacity. During a 20-year period, the expected average statewide population growth is about 26% (4). For this period, two cases will be examined.

Under Case I conditions, existing sewer systems are enlarged to cover a larger service area and existing treatment plants are expanded to receive a larger flow due to new population growth. Thus, water conservation induced reductions in wastewater flows from both existing and new building constructions affect the sizing of new wastewater facilities and are therefore considered. The proportion of flow in a wastewater system at the end of the 20-year period is:

$$\text{Flow from existing construction} = \frac{1.00}{1.26} = 80\%$$

$$\text{Flow from new construction} = \frac{0.26}{1.26} = 20\%$$

The conceptual reduction in the new system capacity, when wastewater flows are decreased due to indoor water use reductions in existing and new buildings constructions is depicted in Figure 6.

Under Case II conditions, new sewer systems and treatments are constructed to serve the new population growth independent of the existing facilities. Thus, water conservation induced reductions in wastewater flows from new building construction only affect the sizing of new wastewater facilities and are therefore considered. The conceptual reduction in the new system capacity is also depicted in Figure 6.

Case I - New Wastewater Facilities Constructed as Additions to Existing Facilities

Case I will be examined first. Some discussions in Case I would be applicable to Case II but will not be always repeated.

Ways to Achieve Indoor Water Use Reduction

More than half of the residential water use in California occurs indoors (5). Figure 7 shows that 74% is used in the bathroom, 22% is used for washing dishes and laundry, and 4% is used for cooking. The greatest potential for water and energy savings occurs in the bathroom where three-fourths of the water used indoors occurs. Conventional tank toilets use about 18.9 litres (5 gallons) of water (6) to rinse the bowl, evacuate the waste, and provide a water trap to prevent the sewer gas from entering the bowl. Most conventional toilets use more water than is needed to perform these functions. The amount of water that is flushed away can be reduced by placing plastic bottles or "water dams" in the toilet tank or by other modifications. On January 1, 1978, a State law (see Appendix A) went into effect that requires low-flush toilets using no more than 13.2 litres (3.5 gallons) per flush in new buildings.

The conventional showerheads deliver up to 45.4 l/min (12 gal/min) (6), which is more water than needed. While the amount of flow desired is variable, depending on personal taste and habits, a survey of more than 5,500 households in the Metropolitan San Diego area in 1977 showed low-flow showers had general consumer acceptance (7). The flow through the showerhead can be controlled by a low-flow showerhead or installing a flow restrictor. In late 1977, the California Energy Commission adopted efficiency standards (see Appendix B) for new showerheads and faucets sold in California after January 1, 1979. The standards set a maximum flow of 10.4 - 11.4 l/min (2.75 - 3.00 gal/min) for showerheads depending upon pressure and 10.4 l/min (2.75 gal/min) for faucets.

The scenarios of water conservation measures to reduce the amount of indoor water use were developed and are shown in Table 16 for three levels of water conservation efforts -- potential, moderate, and minimal. Low-flow toilets, showers, and faucets are considered to be the most important reduction because they are now mandatory in California. These fixtures also provide for most of the water savings. More savings could be achieved by the use of low water-using dish and clothes washers, pressure-reducing valves, and hot water insulation. These measures need to be undertaken voluntarily by the consumers since they are not mandatory and would require public education and promotional campaigns.

The procedures used in developing Table 16 are as follows:

- Identified water conservation measures to be taken.
- Identified the type of building construction in which indoor water use reductions would be made.

- Identified the potential savings for each water conservation measure per household.

- Selected the percent of households installing the various water conservation measures for the three scenarios. A 100% installation rate was used for mandatory measures in new building constructions. The installation rates for the nonmandatory items for new and existing buildings were selected on the basis of judgment, considering various factors including the period of analysis, the expected trend of appliance manufacturers employing water and energy saving features, and the expected replacement rate of appliances and plumbing fixtures in homes.

- The expected indoor water use reductions take into account a mix of existing and new building construction in the community.

- For each scenario, the expected reductions in hot water and total water use were estimated. The scenarios do not include indoor use reduction by such means as correcting leaky faucets or shutting off the faucets when brushing teeth or shaving. Also, advanced technology such as graywater reuse systems, air-assisted showers, and vacuum sewer lines were not included. However, the major conventional water conservation measures, under the current state-of-the-art, are considered as being in the scenarios for the purposes of this study.

Table 16 shows that:

- The reduction in indoor water use will be as follows:

Scenario	Degree of Water Conservation Effort	Percent Reduction in Indoor Water Use
1	Potential	35
2	Moderate	25
3	Minimal	10

- Beyond 20% total reduction in community indoor water use, most of the reductions are caused by retrofitting and replacement of fixtures and appliances in existing construction (see Figure 8).

- The approximate hot water savings will be as follows:

Percent Reduction in Indoor Water Use	Hot Water Savings as[1] Percentage of Total Water Savings
10 - 20	80
30	70
35	60

---

[1] The amount of hot water savings from Table 16 was expressed as a percentage of total savings and plotted against the percent reduction in indoor water use. A curve drawn for the plotted points provided these values.

Relationship Among Flows

In order to assess the benefits and costs, the relationship among design flow, average flow, and average dry weather flow (ADWF) for wastewater facilities must be established. This is necessary because indoor water use (assumed as being similar to the ADWF) can be expressed in terms of average flow and design flow. Average and design flows are used to estimate cost savings (benefits) in wastewater facilities due to water conservation induced reductions in wastewater flow. The following relationship is used:

- Average flow at 100%
- Design flow at 125%
- ADWF at 75%
- Indoor use $\cong$ ADWF

Plant capacities that are representative of small, medium, and large treatment plants are selected as follows:

	Metric Unit	English Unit
° Small	$\leq$ 0.22 m^3/s: use 0.04 and 0.11 m^3/s	$\leq$ 5 mgd: use 0.8 and 2.5 mgd
° Medium	0.22 - 0.88 m^3/s: use 0.55 m^3/s	5.1 - 20 mgd: use 12.5 mgd
° Large	> 0.88 m^3/s: use 1.10 and 2.19 m^3/s	> 20 mgd: use 25 and 50 mgd

These systems will be analyzed at indoor water use reductions of 10%, 20%, 30%, and 35%.

Amount of Water Savings

By applying the indoor water use reduction in existing and new building construction and the flow relationships established, the amount of water savings for various sizes of wastewater systems over a 20-year period can also be determined by using the equation below (see also Table 17):

Total water saved =

$$\left(\begin{array}{l}\text{\% reduction in indoor use}\\ \text{of new building}\\ \text{construction}\end{array}\right) \times \left(\begin{array}{l}\text{Average ADWF new building}\\ \text{construction over a 20-year}\\ \text{period}\end{array}\right)$$

$$+ \left(\begin{array}{l}\text{\% reduction in indoor use}\\ \text{of existing building}\\ \text{construction}\end{array}\right) \times \left(\begin{array}{l}\text{ADWF existing building}\\ \text{construction}\end{array}\right)$$

Where: ADWF = Average dry weather flow

Average ADWF of new building construction over 20-year period =

$$\frac{\text{ADWF new building construction}}{2}$$

ADWF existing building construction =

$$\frac{\text{ADWF new building construction over 20-year period}}{\text{26\% population growth factor}}$$

Hot water saved =

$$\left(\begin{array}{l}\text{Hot water savings as}\\ \text{percentage of total}\\ \text{water savings}\end{array}\right) \times \left(\text{Total water saved}\right)$$

The subtle differences in the percent reductions in indoor water use applied in the above equations and the percent reductions in community indoor water use developed in Table 16 and shown in Figure 8 bear explanation. Let us use an example of 20% overall reduction of indoor water use in the community with a housing mix of existing and new building construction. Thirteen percent of this reduction would be caused by existing buildings and 7% by new buildings, which is a measure of relative reductions in domestic wastewater flow contribution. However, these percentages cannot be directly applied to the above equation for determining the "total water saved". They must first be translated into percent indoor water use reduction for each of the new and existing building constructions separately before wastewater flows become mixed. This can be done by removing the effect of 20%/80% housing mix that was used to determine the 7% and 13% reductions in this example. Therefore,

$$\begin{array}{l}\text{\% reduction of}\\ \text{indoor use in}\\ \text{new buildings}\end{array} = \frac{\begin{array}{l}\text{\% reduction in overall community}\\ \text{indoor water use caused by new}\\ \text{buildings}\end{array}}{\text{\% of new housing in community}} = \frac{7\%}{20\%} = 35\%$$

$$\begin{array}{l}\text{\% reduction of}\\ \text{indoor use in}\\ \text{existing buildings}\end{array} = \frac{\begin{array}{l}\text{of reduction in overall community}\\ \text{indoor water use caused by exist-}\\ \text{ing buildings}\end{array}}{\begin{array}{c}\text{\% of existing housing}\\ \text{in community}\end{array}} = \frac{13\%}{80\%} = 16\%.$$

using the above procedures, the percent reduction of indoor use in the new building construction and in the existing building construction at various levels of overall community indoor water use reductions is as follows:

1	2	3	4	5
Percent Reduction in Overall Community Indoor Water Use (Values from Figure 8)			Percent Reduction in Indoor Water Use	
Total	Caused by Existing Buildings	Caused by New Buildings	In Existing Building Col 2 ÷ 80% Housing Mix	In New Building Col 3 ÷ 20% Housing Mix
10	3.8	6.2	4.8	31.0
20	13.0	7.0	16.3	35.0
30	22.5	7.5	28.1	37.5
35	27.2	7.8	34.0	39.0

Water Supply Benefits

The amount of water saved is treated as the amount of water that does not need to be supplied in the future. The price users are willing to pay for water which otherwise would be needed in the absence of water conservation is measured as the value of water savings. The "willingness to pay" is a difficult value to determine because it is really not known until people are put to the test to pay a particular price. For instance, gasoline prices have risen dramatically in recent years. As the energy crunch continues, people might say that they would be willing to pay $2 or even $4 for a gallon of gas. But no one is certain how much people will actually pay until they are put to the test of doing so. One measure is the price users are willing to pay for water that is equal to the least costly alternative of developing the next increment of California's State Water Project, which is on the order of \$142/dam^3 (\$175/ac-ft)[1] on a statewide basis. The water supply benefits are shown in Table 18 and are determined by multiplying the amount of total water saved from Table 17 times the price of water.

Energy Benefits

Two types of energy benefits were determined. The primary benefits were due to reduction in hot water use, thus requiring less heating energy, and local system energy benefits relating to reduction of treatment and delivery of water supply. The procedures and calculations for determining energy benefits are described below:

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[1] Unpublished data by California Department of Water Resources, Division of Planning, Statewide Planning Branch, 1980.

Water Heating Benefits. The benefits were computed by determining the energy required to heat the amount of water saved and then converting this energy into equivalent barrels of oil valued at \$28 per barrel (bbl). The general equation for the energy benefits =

$$(k_1) \times (\text{amount of hot water saved}) \times (\$28/\text{bbl})$$

Where: $k_1 = 26.1\ \text{bbl/dam}^3\ (32.2\ \text{bbl/ac-ft})$
(a detailed explanation for derivation of k_1 is contained in Appendix C).

The values of annual water heating energy savings are shown in Table 19.

Local Systems Benefits. The reduction in energy required by local systems to treat and convey water supplied to the homes due to water conservation was determined and converted into equivalent barrels of oil.

The general equation for this energy benefit =

$$(k_2)\ (\text{amount of total water saved})\ (\$28/\text{bbl})$$

Where: $k_2 = 0.32\ \text{bbl/dam}^3\ (0.39\ \text{bbl/ac-ft})$
(a detailed explanation of the derivation for k_2 is contained in Appendix C).

The values of annual energy savings in local systems are also shown in Table 19.

Treatment Plant Cost Savings

Capital Cost Savings. The treatment plant process units that could be reduced in size with flow reductions are those based on hydraulic loading and include headworks, primary and secondary clarifiers, effluent chlorination facilities, and effluent outfall (10). It is stressed that the reduction in sewage treatment plant (STP) design flow as a result of water conservation was applied to the above process units but not to the biological process units of secondary treatment. Of the agencies surveyed, two that experienced excessive growth of filamentous bacteria decreased the mean cell residence time in the aeration tanks to rectify the problem. This seems to suggest that some reduction in the size of the tanks may be possible. However, no attempt was made to reduce the size of the aeration tanks because 1) there is no certainty that future water conservation during normal water years would decrease the mass loading of organic constituents as was experienced during the drought years, and 2) a more conservative analysis of water conservation benefits results by not reducing the aeration tanks. The percent reduction in the STP design flow at various levels of reductions in indoor water use can be determined from the following equation:

$$\begin{matrix}\text{Percent Reduction}\\ \text{in STP Design}\\ \text{Flow}\end{matrix} = \frac{\left[\begin{pmatrix}\text{\% Reduction}\\ \text{Indoor Use}\\ \text{New Building}\\ \text{Constr.}\end{pmatrix} \times \begin{pmatrix}\text{ADWF}\\ \text{New}\\ \text{Bldg.}\\ \text{Constr.}\end{pmatrix} + \begin{pmatrix}\text{\% Reduction}\\ \text{Indoor Use}\\ \text{Exist. Bldg.}\\ \text{Constr.}\end{pmatrix} \times \begin{pmatrix}\text{ADWF}\\ \text{Exist.}\\ \text{Bldg.}\\ \text{Constr.}\end{pmatrix}\right] \frac{125}{75}}{\begin{matrix}\text{STP Design Flow}\\ \text{New Bldg. Constr.}\end{matrix}}$$

where:

$$\text{STP Design Flow New Bldg. Constr.} = \text{ADWF New Bldg. Constr.} \times \frac{125}{75}$$

$$\text{ADWF Exist. Bldg. Constr.} = \frac{\text{ADWF New Bldg. Constr.}}{0.26\ \text{Population Growth Factor}}$$

$$\text{Percent Reduction in STP Design Flow} = \frac{\left(\frac{125}{75} \times \text{ADWF New Bldg. Constr.}\right)}{\left(\frac{125}{75} \times \text{ADWF New Bldg. Constr.}\right)} \times \left[\left(\begin{array}{l}\text{\% Reduction}\\ \text{Indoor Use}\\ \text{New Bldg.}\\ \text{Constr.}\end{array}\right) + \left(\frac{\text{\% Reduction Indoor Use Existing Bldg. Constr.}}{0.26\ \text{Population Growth Factor}}\right)\right]$$

$$= \begin{array}{l}\text{\% Reduction}\\ \text{Indoor Use}\\ \text{New Bldg. Constr.}\end{array} + \frac{\text{\% Reduction Indoor Use Exist. Bldg. Constr.}}{0.26\ \text{Population Growth Factor}}$$

By using the percent reductions in indoor water use in the new and existing building constructions previously determined, the above equation gives the following reductions in the STP design flow:

Percent Reduction in Overall Community Indoor Use	Percent Reduction in Indoor Use New Bldg. Constr.	Percent Reduction in Indoor Use Exist. Bldg. Constr.	Percent Reduction[1/] in STP Design Flow (From Above Equation)
10	31.0	4.8	49.5
20	35.0	16.3	97.7
30	37.5	28.1	100
35	39.0	34.0	100

The capital cost of a secondary treatment can be expressed as a function of design flow, $Q^{0.89}$ (9). The percent reduction in the cost then can be determined by applying the function $Q^{0.89}$ to the percent reduction in the design flow. For example,

Let design Q = 10. Then $(10)^{0.89} = 7.76$

At a reduction in overall community indoor water use of 20%, design $Q_{\text{reduction}} = (10)\ (97.7\%) = 9.77$.

Then, design $Q^{0.89}_{\text{reduction}} = (9.77)^{0.89} = 7.60$

$$\text{\% reduction in capital cost} = \frac{7.60}{7.76} = 97.9\%$$

[1/] Values only apply to plant process units affected by hydraulic load. Reduction cannot exceed 100%

However, the entire plant cannot be reduced in size because all the process units are not sized on wastewater flow rate. As discussed earlier, the process units which are affected by hydraulic load are headworks, primary and secondary clarifiers, effluent chlorination facilities, and effluent outfall.

These units constitute about 22%[1/] of the total secondary treatment plant costs. The reduction in capital cost in this illustration amounts to (97.9%) (22%) = 21.5%. Using this procedure, the percent reduction in the capital cost increases linearly to a maximum of 22% at 21% to 35% reduction in indoor use (see Table 20 and Figure 9).

The capital cost of a secondary treatment plant can be estimated by using the simplified procedure suggested in EPA Report MCD-37 (9). The equation for the cost is expressed as:

$$\text{Cost } (\$1{,}000) = kQ^{0.89}$$

	Metric Unit	English Unit
where: k = constant	40 806	2,523
Q = plant capacity =	in m^3/s	in mgd

The annual capital cost savings for secondary treatment plants are shown in Table 21 by multiplying the values obtained by using the above equation times the percent reduction in treatment plant capital cost from Table 20.

O&M Cost Savings. As discussed earlier, cost data from nine secondary treatment plants were evaluated. The percent change in the O&M costs varied in a "scatter shot" pattern from -5% to about +4% (see Figure 5). Because of this variance and because the average difference amounted to only -0.3%, no attempt was made to adjust the O&M costs.

Sewer System Cost Savings

Capital Cost Savings. Because the sewer design flow is directly proportional to the ADWF (similar to indoor water use), the percent reduction in the sewer design flow is the same as the percent reduction in indoor water use. The percent reduction in indoor water use determined in the analysis of the treatment plant capital cost savings also applies to the sewer system. However, the sewer systems that serve the new and existing buildings must be examined separately because they are essentially in parallel operation. For example, the effects of a 30% overall community reduction in indoor water use are as follows:

[1/] Based on information from EPA Report MCD-37, "Construction Costs for Municipal Waste Water Treatment Plants: 1973-1977" January 1978 (9) and represents an average of 25% for activated sludge plants and 20% for trickling filter plants.

New sewer system:

- Percent reduction in indoor use = 37.5%
- Reduction affects capital and O&M costs.

Existing sewer system:

- Percent reduction in indoor use = 28.1%
- Reduction affects O&M costs only.

The determination of the sewer design flow depends on many factors such as climate, population growth, domestic, commercial, institutional, and industrial discharges, topography, and the judgment of the design engineers. In assessing any water conservation induced reduction in pipe sizes, it is prudent then to work within a range of sewer design flows rather one specific design flow for a given pipe size. Therefore, the range of design flows for various pipe sizes shown in EPA Report MCD-38 (11) was used. The percent reductions in the sewer design flow as a result of wastewater flow reductions were used to determine the new sewer design flows and the new pipe size selections. A sample calculation is shown in Table 22. Using this procedure, the complete new pipe size selections are shown in Table 23. It was found that:

- For sewer systems requiring a maximum pipe size of 137.2 cm (54 inches), pipes can be selected one size smaller at 10%, 20%, 30%, and 35% reductions in overall community indoor water use.

- For sewer systems requiring a maximum pipe size of 152.4 cm (60 inches) to 213.4 cm (84 inches), pipes can be selected one size smaller at 10% reduction and two sizes smaller at 20%, 30%, and 35% reductions.

In order to estimate the capital cost savings for the sewer lines, it was necessary to determine the capital cost with and without flow reduction and assume the following conditions for California.

- Average occupants per home = 2.75 (12)
- Typical residential frontage = 18.3 m (60 ft)[1/]
- Length of sewer collector pipe = $\frac{18.3 \text{ m}}{2.75 \text{ occupants/home}}$ = 6.7 m/capita (21.8 ft/capita)

- Length of sewer interceptor = 0.3 m/4.9 m of collector pipe (1 ft/16 ft) from EPA Report MCD-38 (11)

$$= 0.3\text{m} \times \frac{6.7 \text{ m}}{4.9 \text{ m}} = 0.4 \text{ m per capita}$$

[1/] Typical residential frontage is on the order of 18.3 m (60 ft) based on information from the Sacramento County Assessor's Office.

- Total sewer pipe length required = 6.7 + 0.4 = 7.1 m/capita (23 ft/capita)

- Average indoor residential use = 3.3×10^{-6} m^3/s per capita (75 gal/capita/day). From references (13) and (14).

A sample calculation for the sewer pipe capital cost without flow reduction and with flow reduction is shown in Tables 24 and 25, respectively. Savings in capital cost of sewer pipes are:

Equivalent Annual Cost w/o Indoor Use Reduction = $1,470,000

Equivalent Annual Cost w/Indoor Use Reduction at 10%, 20%, 30%, and 35% = $1,265,000

Cost Savings = $1,470,000 - 1,265,000 = $205,000/yr.

Using this procedure, the capital cost of the sewer lines and the cost savings for the various size systems are shown in Table 26.

O&M Cost Savings. The annual O&M cost for sewer systems can be estimated by using the procedure suggested in EPA report MCD-39 (15). For a sewer system that is integrated with the operation of the treatment plant, the O&M cost is shown at $6.35 per capita. The cost adjusted to 1979 dollars = $7.05 per capita. The population served is estimated by choosing a unit indoor use of $3/29 \times 10^{-6}$ m^3/s per capita (75 gal/capita/day).

The savings in sewer O&M costs must be examined separately for existing and new sewer systems. The percent reductions in O&M costs based on actual survey data previously discussed are obtained from Figure 2 at various levels of wastewater flow reductions and are shown in Table 27. The percent reductions are applied to the annual O&M cost, and the annual dollar savings for new and existing sewer savings are shown in Tables 28 and 29, respectively, and combined in Table 30.

Summary of Water Conservation Benefits, Case I

Case I water conservation benefits consisting of energy and water supply benefits and treatment plant and sewer system cost savings are summarized in Tables 31 through 34 at 10%, 20%, 30%, and 35% reductions in indoor water use. An example of the benefits for a corresponding treatment plant size of 0.55 m^3/s (12.5 mgd) is depicted in Figure 10. It is evident that the major benefits come from energy savings.

Case II - New Wastewater Facilities Constructed Independent of Existing Facilities

Case II will be examined in this section in a manner similar to Case I. Some discussions in Case I will be applicable to Case II but will not be repeated in all instances. Case II is a condition whereby new wastewater facilities serve new population growth and operate independent of existing facilities. Thus, Case II considers wastewater flows from new building construction only.

Ways to Achieve Indoor Water Use Reduction

From the scenarios of water conservation measures examined for Case I, the expected percent reductions in indoor water use pertaining to new building construction only are shown in Table 35 and summarized as follows:

Scenario	Degree of Water Conservation Effort	Percent Reduction in Indoor Water Use	Hot Water Savings[1/] as Percentage of Total Water Savings
1	Potential	40	55
2	Moderate	35	60
3	Minimal	30	55

Relationship Among Flows

The flow relationships established for Case I will be applicable to Case II. The small, medium, and large wastewater facilities will be analyzed at indoor water use reductions of 30%, 35%, and 40%. The relationship between indoor water use reductions and treatment plant design flows are as follows:

- 30% reduction in indoor use = 30% x $\frac{75\%}{125\%}$ x design flow

  = 18% of plant design flow

- 35% reduction in indoor use = 21% of plant design flow

- 40% reduction in indoor use = 24% of plant design flow.

Amount of Water Savings

Based on the indoor water use reductions and flow relationships previously discussed, the amount of total water savings at 30%, 35%, and 40% indoor use reductions were estimated (see Table 36).

Water Supply Benefits

The water supply benefits are determined in the same manner as in Case I and are shown in Table 37.

Energy Benefits

The water heating and local systems energy benefits are determined in the same way as in Case I. The only difference is the amount of water savings. The annual benefits are shown in Table 38.

1/ From Table 35.

Treatment Plant Cost Savings

The capital cost of secondary treatment plants can be estimated by using the simplified procedure suggested in EPA Report MCD-37 (9). The equation for the cost is expressed as:

$$\text{Cost } (\$1000) = kQ^{0.89}$$

where:

		Metric Unit	English Unit
k = constant	=	40 806	2,523
Q = plant capacity	=	in m^3/s	in mgd

By applying this equation at various levels of indoor use reduction, the treatment plant capital costs are decreased linearly to 36.5% at 40% reduction in indoor use.

The treatment plant process units that could be reduced in size with flow reductions are those based on hydraulic loading and include (10):

- Headworks
- Primary and secondary clarifiers
- Effluent chlorination facilities
- Effluent outfall.

These units constitute about 22%[1] of the total treatment plant costs. Therefore, the capital cost savings increases linearly to (36.5%) x (22%) = 8% at 40% reduction in indoor use (see Figure 11). Using the cost reduction shown in Figure 11, the savings in capital costs at various levels of flow reduction are shown on Table 39.

As discussed earlier, cost data from nine secondary treatment plants were evaluated. The percent change in the O&M costs varied in a "scatter shot" pattern from -5% to about +4% (see Figure 5). Because of this variance and because the average difference amounted to only -0.3%, no attempt was made to adjust the O&M costs.

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[1] Based on information from EPA Report MCD-37, "Construction Costs for Municipal Waste Water Treatment Plants: 1973-1977" January 1978 (9) and represents an average of 25% for activated sludge plants and 20% for trickling filter plants.

Sewer System Cost Savings

Capital Cost Savings. The sizing of collector and interceptor sewers was assessed in a way similar to Case I. It was found that the reductions in pipe size selections were essentially the same as that for the new sewer system in Case I. The capital cost of the sewer lines and the cost savings for the various size systems were determined in the same manner as in Case I and are shown in Table 40. The average savings for the capital cost of the sewer lines at all levels of indoor water use reductions is about 7%.

O&M Cost Savings. The annual O&M cost for sewer systems can be estimated by using the procedure suggested in EPA Report MCD-39 (15). For a sewer system that is integrated with the operation of the treatment plant, the O&M cost is shown at $6.35 per capita. The cost adjusted to 1979 dollars = $7.05 per capita. The population served is estimated by choosing a unit indoor use of 3/ 29x10^{-6} m^3/s per capita (75 gal/capita/day). The percent reductions in O&M cost based on actual survey data previously discussed (see Figure 2) are:

Percent Reduction In Indoor Water Use	Percent Reduction In Sewer O&M Cost
30	1.5
35	1.8
40	2.2

The annual cost savings in sewer O&M costs are shown in Table 41.

Summary of Water Conservation Benefits, Case II

Case II water conservation benefits consisting of energy and water supply benefits and treatment plant and sewer system cost savings are summarized in Tables 42 thru 44 at 30%, 35%, and 40% reductions in indoor use. An example of the benefits for a 0.55 m^3/s (12.5 mgd) treatment plant size are graphically depicted in Figure 12. It is evident that the major benefits come from energy and sewer system cost savings.

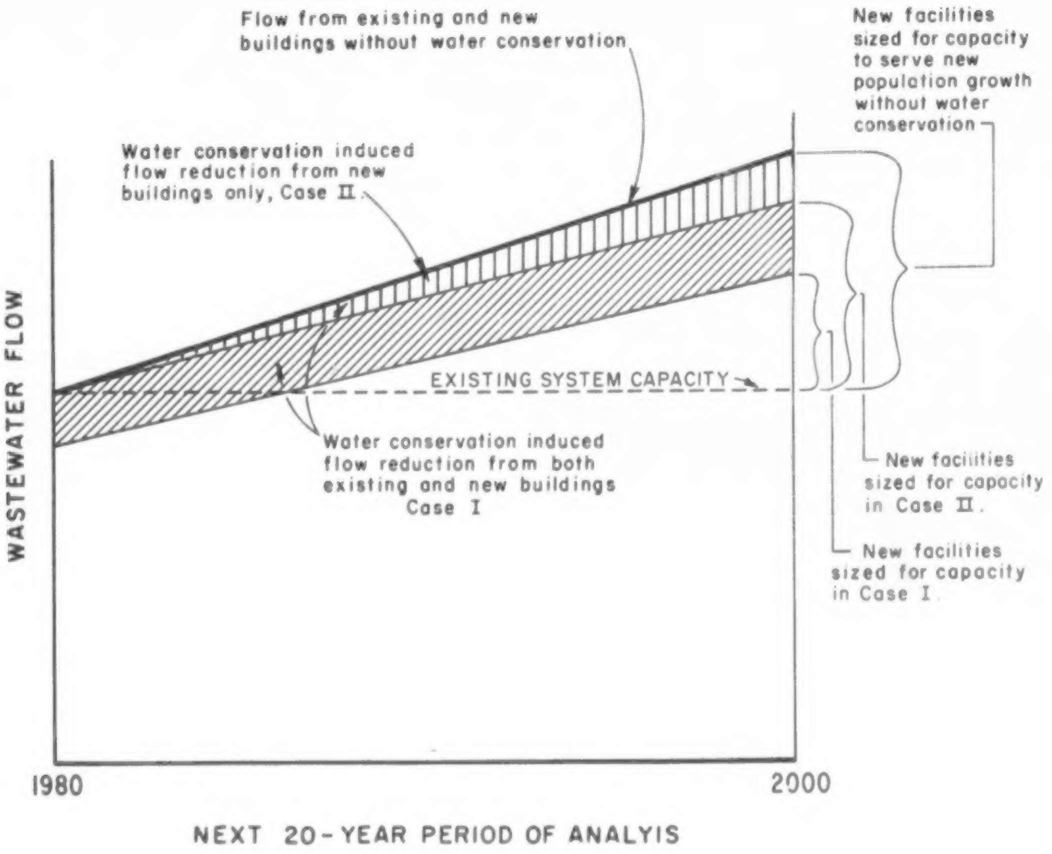
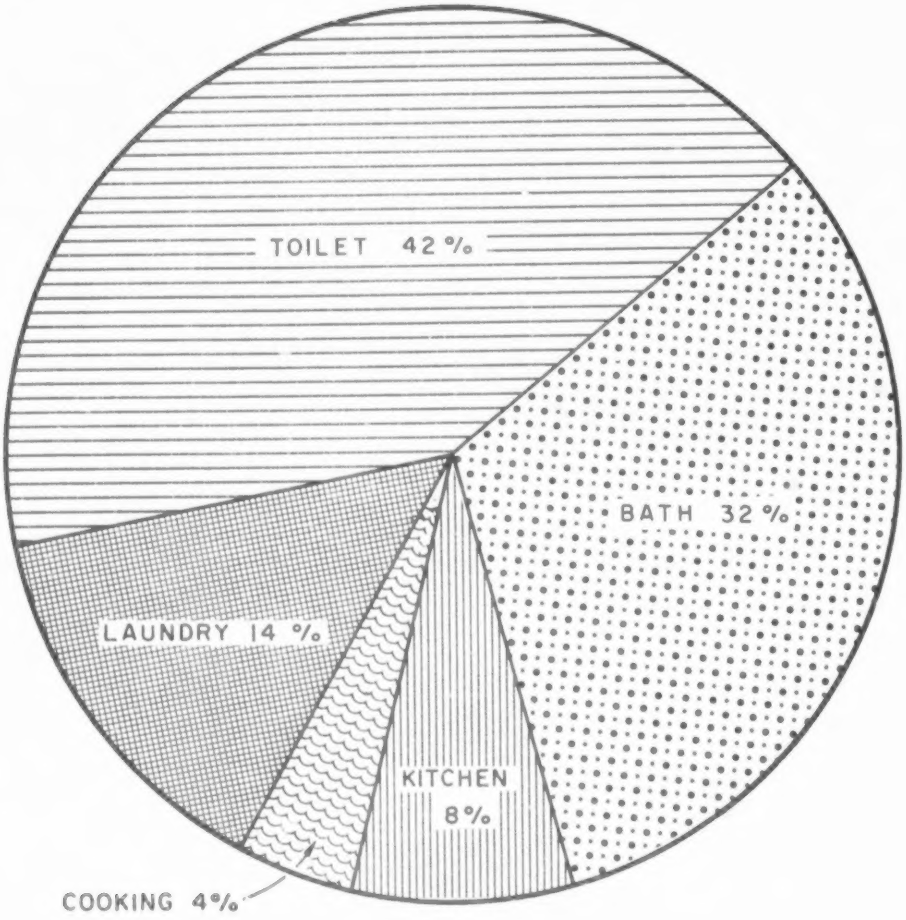


Figure 6. Effect of wastewater flow reduction on new wastewater system capacity.



SOURCE: Bulletin 198, "Water Conservation in California", May 1976, California Department of Water Resources (5)

Figure 7. Residential water use in California.

TABLE 16. PERCENT EXPECTED REDUCTIONS IN COMMUNITY INDOOR WATER USE RESULTING FROM WATER CONSERVATION MEASURES[1]
(Case I - Mix of Existing and New Building Construction)

			Scenario 1-Potential		Scenario 2-Moderate Water Conservation Effort		Scenario 3-Minimal Water Conservation Effort	
Measures	Type of Construction	Potential Reduction (in percent)	Households[2] Installing (in percent)	Expected Reduction (in percent)	Households[2] Installing (in percent)	Expected Reduction (in percent)	Households[2] Installing (in percent)	Expected Reduction (in percent)
Toilet	New	14[4]	100	2.8	100	2.8	100	2.8
	Existing	9.5[5]	100	7.5	30	2.3	-0-	-0-
Shower[3]	New	12[6]	100	2.4	100	2.4	100	2.4
	Existing	12[6]	100	9.6	90	8.6	15	1.4
Faucet[3]	New	2[7]	100	0.4	100	0.4	100	0.4
	Existing	2[7]	100	1.6	90	1.4	15	0.2
Pressure Reducing Valve	New	4[7]	100	0.8	10	0.1	-0-	-0-
	Existing	4[7]	100	3.2	5	0.2	-0-	-0-
Hot[3] [8] Water Pipe Insulation	New	2[7]	100	0.4	50	0.2	-0-	-0-
	Existing	2[7]	60	1.0	5	0.1	-0-	-0-
Clothes Washer[3]	New	5[7] [9]	100	1.0	100	1.0	50	0.5
	Existing	5[7] [9]	100	4.0	100	4.0	50	2.0
Dish Washer[3]	New	0.5[10]	100	0.1	100	0.1	100	-0-
	Existing	0.5[10]	100	0.4	100	0.4	50	0.2
Hot Water Savings	New			4.3		4.1		3.3
	Existing			16.6		14.5		3.8
	Total			20.9		18.6		8.1
Hot and Cold Water Savings	New			7.9		7.0		6.1
	Existing			27.4		17.0		3.8
	Total			35.3		24.0		9.9
	Rounded			35		25		10

NOTE: See next page for footnotes.

FOOTNOTES FOR TABLE 16

1/ For the various scenarios, the expected reductions are determined by multiplying the reduction potential times percent of households installing the measures times 80 percent for existing building construction and 20 percent for new building construction.

2/ Percent of households installing water conservation measures.

3/ Measures generating hot water energy savings.

4/ Use volume of conventional toilets = 19.76 litres (5.22 gallons). California Department of Water Resources (DWR) Bulletin 191, Appendix G (6). Low-flush toilets = 13.2 litres (3.5 gal) per flush (mandatory).

$$\text{Savings} = \frac{\text{6.51 litres (1.72 gal)}}{\text{19.76 litres (5.22 gal)}} = \text{33 percent per flush.}$$

Toilet use = 42 percent of indoor use. Therefore, 33 percent times 42 percent equals 14 percent of indoor use saved by low-flush toilets.

5/ Average savings of common retrofit devices (toilet dams, bottles, and plastic bags) = 4.5 litres (1.2 gal) per flush. DWR Bulletin 191, Appendix G (6).

$$\text{Savings} = \frac{\text{4.5 litres (1.2 gal)}}{\text{19.76 litres (5.22 gal)}} = \text{23 percent per flush.}$$

Toilet use = 42 percent of indoor use. Therefore, 23 percent times 42 percent equals 9.5 percent of indoor use saved by retrofitting existing toilets.

6/ Average flow of conventional showerheads at 310 kilopascals (45 psi) equals 31.61 litres per minute (8.35 gpm). DWR Bulletin 191, Appendix G (6). Flow of low-flow showerheads = 11.36 litres per minute (3 gpm) (mandatory).

$$\text{Savings} = \frac{\text{20.25 litres/min (5.35 gal/min)}}{\text{31.61 litres/min (8.35 gal/min)}}$$
$$= \text{64 percent per shower}$$

Daily use per household based on data in DWR Bulletin 206 Appendix
(8): Shower = 2.6 times
Bathtub = 1.8 times

Volume of shower use = 31.61 litres/min (8.35 gpm) x 6 min x 2.6 = 492 litres (130 gal)
Volume of tub use = 189 litres (50 gal) x 1.8 = 341 litres (90 gal)
Total equals 833 litres (220 gal)

Bathing use = 32% of indoor use. Therefore, shower savings = 64% savings x $\frac{\text{492 litres (130 gal)}}{\text{833 litres (220 gal)}}$ x 32% = 12% of indoor use

(continued)

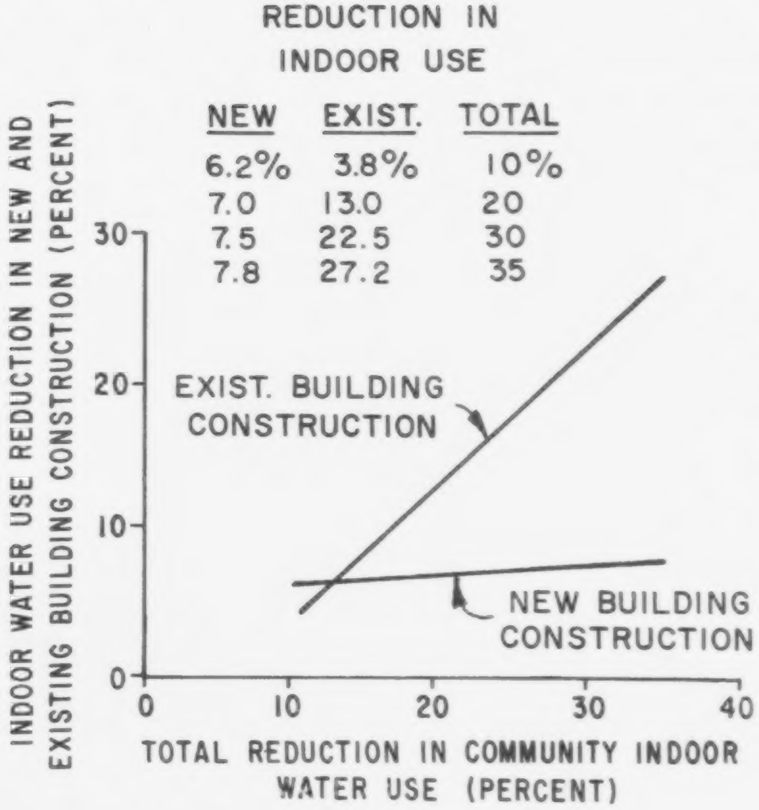
FOOTNOTES FOR TABLE 16 (continued)

7/ DWR Bulletin 198 (5).

8/ Generates hot water savings because less water needs to be run through the faucet before hot water begins to flow.

9/ Assumes that all new machines manufactured in the next 20 years will employ a water saving feature. While not all households will own washers, the assumption is that they will be using water saving machines at the laundromat.

10/ Assumes that all dishwashers manufactured in the next 20 years will employ a water saving feature. 24 percent of households own dishwashers. DWR Bulletin 198 (5).


REDUCTION IN INDOOR USE

NEW	EXIST.	TOTAL
6.2%	3.8%	10%
7.0	13.0	20
7.5	22.5	30
7.8	27.2	35

Figure 8. Reduction in indoor water use, Case I.

TABLE 17. AMOUNT OF WATER SAVINGS, CASE I

Treatment Plant Design Flow m^3/s (mgd)	ADWF 1/ New Bldg Construction m^3/s (mgd)	Average 2/ ADWF New Bldg Construction over 20-year period m^3/s (mgd)	ADWF 3/ Existing Construction m^3/s (mgd)	Percent Overall Reduction in Total Community Indoor Water Use	Percent Reduction in Indoor Water Use		Total Water 4/ Saved dam^3 (ac-ft)			Hot 5/ Water Saved dam^3 (ac-ft)
					New Bldg Construction	Existing Bldg Construction	New Bldg Construction	Existing Bldg Construction	Total	
0.04 (0.8)	0.02 (0.48)	0.01 (0.24)	0.08 (1.85)	10	31.0	4.8	102 (83)	122 (99)	224 (182)	180 (146)
				20	35.0	16.3	116 (94)	417 (338)	533 (432)	427 (346)
				30	37.5	28.1	125 (101)	718 (582)	842 (683)	590 (478)
				35	39.0	34.0	130 (105)	868 (704)	998 (809)	598 (485)
0.11 (2.5)	0.07 (1.5)	0.03 (0.75)	0.25 (5.77)	10	31.0	4.8	321 (260)	382 (310)	703 (570)	562 (456)
				20	35.0	16.3	363 (294)	1 299 (1,053)	1 662 (1,347)	1 330 (1,078)
				30	37.5	28.1	389 (315)	2 240 (1,816)	2 629 (2,131)	1 840 (1,492)
				35	39.0	34.0	405 (328)	2 710 (2,197)	3 115 (2,525)	1 869 (1,515)

1/ ADWF = Average dry weather flow.

2/ Average ADWF of new construction over 20-year period = $\frac{\text{ADWF new construction}}{2}$

3/ ADWF existing construction = $\frac{\text{ADWF new construction}}{\text{26\% growth factor}}$

4/ Total water saved =
(% reduction in indoor use of exist. constr.) x (Av. ADWF new constr. over 20-year period)
(% reduction in indoor use of exist. constr.) x (ADWF exist. constr.)

5/ Hot water saved = (Hot water savings as % of total water savings) x (total water saved)

(continued)

TABLE 17 (continued)

Treatment Plant Design Flow m^3/s (mgd)	ADWF[1/] New Bldg Construction m^3/s (mgd)	Average[2/] ADWF New Bldg Construction over 20-year period m^3/s (mgd)	ADWF[3/] Existing Construction m^3/s (mgd)	Percent Overall Reduction in Total Community Indoor Water Use	Percent Reduction in Indoor Water Use		Total Water[4/] Saved dam^3 (ac-ft)			Hot[5/] Water Saved dam^3 (ac-ft)
					New Bldg Construction	Existing Bldg Construction	New Bldg Construction	Existing Bldg Construction	Total	
0.55 (12.5)	0.33 (7.5)	0.16 (3.75)	1.26 (28.8)	10	31.0	4.8	1 606 (1,302)	1 909 (1,548)	3 515 (2,850)	2 812 (2,280)
				20	35.0	16.3	1 830 (1,470)	6 486 (5,258)	8 299 (6,728)	6 639 (5,382)
				30	37.5	28.1	1 943 (1,575)	11 180 (9,064)	13 123 (10,639)	9 186 (7,447)
				35	39.0	34.0	2,020 (1,638)	13 528 (10,967)	15 548 (12,605)	9 440 (7,653)
1.10 (25)	0.66 (15)	0.33 (7.5)	2.53 (57.7)	10	31.0	4.8	3 212 (2,604)	3,826 (3,102)	7,038 (5,706)	5,631 (4,565)
				20	35.0	16.3	3 626 (2,940)	12 994 (10,534)	16 620 (13,474)	13 296 (10,779)
				30	37.5	28.1	3 886 (3,150)	22 399 (18,159)	26 285 (21,309)	18 399 (14,916)
				35	39.0	34.0	4 041 (3,276)	27 102 (21,972)	31 143 (25,248)	18 686 (15,149)

1/ ADWF = Average dry weather flow.

2/ Average ADWF of new construction over 20-year period = $\frac{\text{ADWF new construction}}{2}$

3/ ADWF existing construction = $\frac{\text{ADWF new construction}}{\text{26\% growth factor}}$

4/ Total water saved =
(% reduction in indoor use of exist. constr.) x (Avg. ADWF new constr. over 20-year period)
(% reduction in indoor use of exist. constr.) x (ADWF exist. constr.)

5/ Hot water saved = (Hot water savings as % of total water savings) x (total water saved)

(continued)

TABLE 17 (continued)

Treatment Plant Design Flow m^3/s (mgd)	ADWF[1/] New Bldg Construction m^3/s (mgd)	Average[2/] ADWF New Bldg Construction over 20-year period m^3/s (mgd)	ADWF[3/] Existing Construction m^3/s (mgd)	Percent Overall Reduction in Total Community Indoor Water Use	Percent Reduction in Indoor Water Use		Total Water[4/] Saved dam^3 (ac-ft)			Hot[5/] Water Saved dam^3 (ac-ft)
					New Bldg Construction	Existing Bldg Construction	New Bldg Construction	Existing Bldg Construction	Total	
2.19 (50)	1.31 (30)	0.66 (15)	5.06 (115.4)	10	31.0	4.8	6 424 (5,208)	7 653 (6,204)	14 077 (11,412)	11 262 (9,130)
				20	35.0	16.3	7 253 (5,880)	25 986 (21,067)	33 239 (26,947)	26 592 (21,558)
				30	37.5	28.1	7 771 (6,300)	44 799 (36,319)	52 571 (42,619)	36 799 (29,833)
				35	39.0	34.0	8 082 (6,552)	54 205 (43,944)	62 287 (50,496)	37 373 (30,298)

1/ ADWF = Average dry weather flow.

2/ Average ADWF of new construction over 20-year period = $\frac{\text{ADWF new construction}}{2}$

3/ ADWF existing construction = $\frac{\text{ADWF new construction}}{\text{26\% growth factor}}$

4/ Total water saved =
(% reduction in indoor use of exist. constr.) x (Av. ADWF new constr. over 20-year period)
(% reduction in indoor use of exist. constr.) x (ADWF exist. constr.)

5/ Hot water saved = (Hot water savings as % of total water savings) x (total water saved)

TABLE 18. WATER SUPPLY BENEFITS, CASE I

Treatment Plant Design Flow m^3/s (mgd)	Annual Water Supply Benefits at Various Levels of Indoor Use Reduction (in $1,000)			
	10%	20%	30%	35%
0.04 (0.8)	30	75	120	140
0.11 (2.5)	100	235	275	440
0.55 (12.5)	500	1,175	1,860	2,205
1.10 (25)	1,000	2,360	2,730	4,420
2.19 (50)	1,995	4,715	7,460	8,835

TABLE 19. ANNUAL ENERGY BENEFITS, CASE I (in $1,000)

Treatment Plant Size m^3/s (mgd)	Water Heating	Local Systems	Total[1]
At 10 Percent Reduction in Indoor Use			
0.04 (0.8)	132	+2	135
0.11 (2.5)	411	6	415
0.55 (12.5)	2,056	31	2,085
1.10 (25)	4,116	62	4,180
2.19 (50)	8,232	125	8,355
At 20 Percent Reduction			
0.04 (0.8)	312	5	315
0.11 (2.5)	972	15	985
0.55 (12.5)	4,852	73	4,925
1.10 (25)	9,718	147	9,865
2.19 (50)	19,437	294	19,730
At 30 Percent Reduction			
0.04 (0.8)	431	7	440
0.11 (2.5)	1,345	23	1,370
0.55 (12.5)	6,714	116	6,830

---

[1] Rounded to the nearest $5,000

(continued)

TABLE 19 (continued)

Treatment Plant Size m^3/s (mgd)	Water Heating	Local Systems	Total[1]
1.10 (25)	13,448	233	13,680
2.19 (50)	26,897	465	27,360
	At 35 Percent Reduction		
0.04 (0.8)	437	9	445
0.11 (2.5)	1,366	28	1,395
0.55 (12.5)	6,900	138	7,040
1.10 (25)	13,658	276	13,935
2.19 (50)	27,317	551	27,870

[1] Rounded to the nearest $5,000

TABLE 20. PERCENT REDUCTION IN SECONDARY TREATMENT PLANT (STP) CAPITAL COSTS DUE TO FLOW REDUCTIONS

% Reduction in Overall Community Indoor Water Use	% Reduction[1/] in STP Design Flow (Design Q)	Design $Q_{Reduction}$	Design 0.89 $Q_{Reduction}$	% Reduction[1/] in STP Capital Cost (Total Plant Sized Smaller)	% Reduction in STP Capital Cost Units Affected By Hydraulic Load (22%) Sized Smaller
10	49.5	4.95	4.15	53.5	11.8
20	97.7	9.77	7.60	97.9	21.5
30	100.0	10.0	7.76	100.0	22.0
35	100.0	10.0	7.76	100.0	22.0

[1/] Reduction cannot exceed 100%

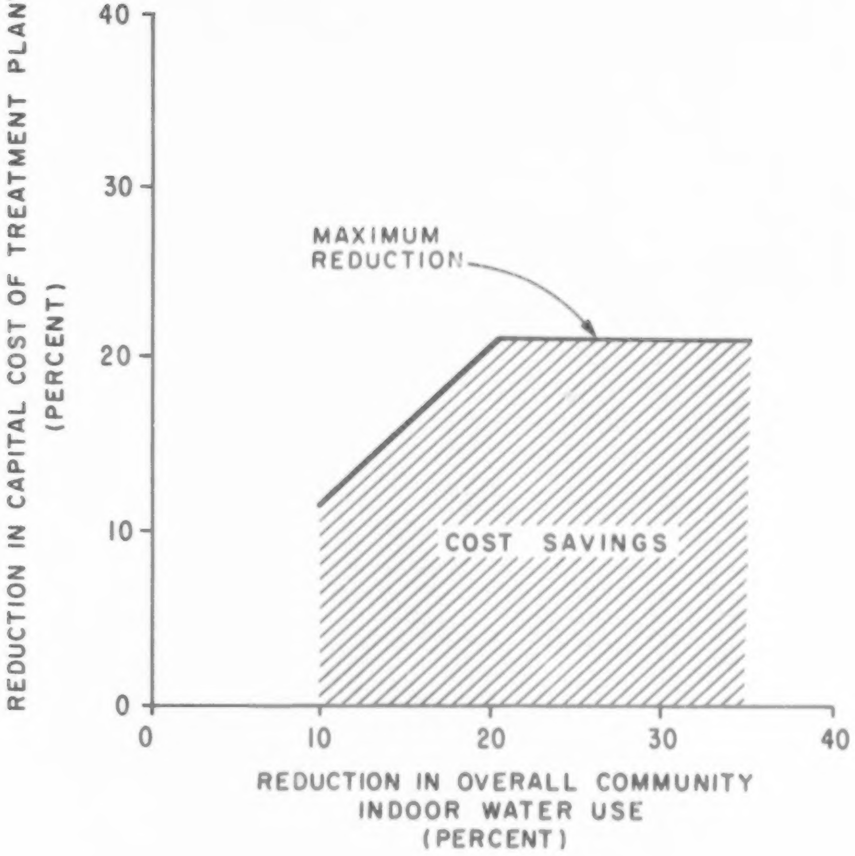


Figure 9. Percent reduction in treatment plant capital cost, Case I.

TABLE 21. CAPITAL COST SAVINGS FOR SECONDARY TREATMENT PLANTS, CASE I

Treatment Plant Size in m^3/s (mgd)	Equiv. Annual Capital Cost[1] (in $1,000)	Annual Capital Cost Savings For Treatment Plants (in $1,000)				
		Flow Reduction =	10%	20%	30%	35%
		Cost[2] Reduction =	11.8%	21.5%	22.0%	22.0%
0.04 (0.8)	280		35	60	60	60
0.11 (2.5)	660		80	140	145	145
0.55 (12.5)	2,460		290	530	540	540
1.10 (25)	5,110		605	1,100	1,125	1,125
2.19 (50)	9,470		1,115	2,035	2,085	2,085

1/ Cost derived from the equation, cost = $kQ^{0.89}$, adjusted from national average to California prices, adjusted to reflect 1979 dollars (EPA cost index) with a 7% interest rate and 25 years of service life.

2/ From Table 20.

TABLE 22. SAMPLE CALCULATION FOR REDUCING NEW SEWER PIPE SIZES DUE TO REDUCTIONS IN WASTEWATER FLOW

1 Design1/ Discharge Range m^3/s (mgd)	2 Midpoint of Design Discharge Range m^3/s (mgd)	3 Pipe1/ Diameter cm (inches)	4 Percent Reduction in Overall Community Indoor Water Use	5 Percent Reduction in Sewer Design Flow	6 Reduction in Sewer Design Flow m^3/s (mgd) Col. 2 x Col. 5	7 New Sewer Design Flow m^3/s (mgd) Col. 2 - Col. 6	8 New1/ Pipe Diameter cm (inches)
0.02-0.04 (0.47-0.82)	0.03 (0.65)	38.1 (15)	10	31.0	0.009 (0.20)	0.021 (0.45)	30.5 (12)
			20	35.0	0.009 (0.23)	0.021 (0.42)	30.5 (12)
			30	37.5	0.011 (0.24)	0.019 (0.41)	30.5 (12)
			35	39.0	0.011 (0.25)	0.019 (0.40)	30.5 (12)
0.04-0.06 (0.82-1.3)	0.05 (1.06)	45.7 (18)	10	31.0	0.014 (0.33)	0.036 (0.73)	38.1 (15)
			20	35.0	0.018 (0.37)	0.032 (0.69)	38.1 (15)
			30	37.5	0.019 (0.40)	0.031 (0.66)	38.1 (15)
			35	39.0	0.020 (0.41)	0.030 (0.65)	38.1 (15)
0.06-0.08 (1.3-1.9)	0.07 (1.60)	53.3 (21)	10	31.0	0.022 (0.50)	0.048 (1.10)	45.7 (18)
			20	35.0	0.022 (0.56)	0.048 (1.04)	45.7 (18)
			30	37.5	0.027 (0.60)	0.043 (1.00)	45.7 (18)
			35	39.0	0.027 (0.62)	0.043 (0.98)	45.7 (18)

1/ From EPA Report MCD-38 (11).

TABLE 23. SMALLER SEWER PIPE SIZE SELECTION DUE TO WASTEWATER FLOW REDUCTION, CASE I

Original Pipe Diameter in centimetres (inches)	New Pipe Diameter in centimetres (inches)				
	Percent Reduction in Overall Community Indoor Water Use	10	20	30	35
	Percent Reduction in Sewer Design Flow	31	35	37.5	39
20.3 (8)		15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
25.4 (10)		20.3 (8)	20.3 (8)	20.3 (8)	20.3 (8)
30.5 (12)		25.4 (10)	25.4 (10)	25.4 (10)	25.4 (10)
38.1 (15)		30.5 (12)	30.5 (12)	30.5 (12)	30.5 (12)
45.7 (18)		38.1 (15)	38.1 (15)	38.1 (15)	38.1 (15)
53.3 (21)		45.7 (18)	45.7 (18)	45.7 (18)	45.7 (18)
61.0 (24)		53.3 (21)	53.3 (21)	53.3 (21)	53.3 (21)
68.6 (27)		61.0 (24)	61.0 (24)	61.0 (24)	61.0 (24)
76.2 (30)		68.6 (27)	68.6 (27)	68.6 (27)	68.6 (27)
91.4 (36)		76.2 (30)	76.2 (30)	76.2 (30)	76.2 (30)
106.7 (42)		91.4 (36)	91.4 (36)	91.4 (36)	91.4 (36)
121.9 (48)		106.7 (42)	106.7 (42)	106.7 (42)	106.7 (42)
137.2 (54)		121.9 (48)	121.9 (48)	121.9 (48)	121.9 (48)
152.4 (60)		137.2 (54)	121.9 (48)	121.9 (48)	121.9 (48)
167.6 (66)		152.4 (60)	137.2 (54)	137.2 (54)	137.2 (54)
182.9 (72)		167.6 (66)	152.4 (60)	152.4 (60)	152.4 (60)
213.4 (84)		182.9 (72)	167.6 (66)	167.6 (66)	167.6 (66)

▨ Pipe selection 1 size smaller ▧ Pipe selection 2 sizes smaller

TABLE 24. SAMPLE CALCULATION FOR SEWER PIPE CAPITAL COST WITHOUT REDUCTION IN INDOOR WATER USE, CASE I

1	2	3	4	5	6	7
Pipe Size cm (inches)	Percent[1] of Total Length	Length of Pipe m (feet)	Average[2] Unit Cost \$/m (\$/ft)	Pipe[3] Cost \$1,000 Col. 3 x Col. 4	Adjusted[4] Pipe Cost \$1,000	Equivalent[5] Annual Cost \$1,000
15.2 (6)	67.7	94 920 (311,420)	79 (24)	7,470		
20.3 (8)	16.1	22 570 (74,060)	141 (43)	3,180		
25.4 (10)	5.1	7 150 (23,460)	154 (47)	1,100		
30.5 (12)	3.7	5 190 (17,020)	194 (59)	1,000		
38.1 (15)	3.1	4 350 (14,260)	240 (73)	1,040		
45.7 (18)	1.9	2 660 (8,740)	308 (94)	820		
53.3 (21)	1.5	2 100 (6,900)	387 (118)	810		
61.0 (24)	0.9	1 260 (4,140)	407 (124)	510		
	100.0	140 200 (460,000)		15,930	20,340	1,470

NOTE: This sample calculation pertains to a corresponding treatment plant size of 0.11 m^3/s (2.5 mgd). For this size system, the following applies:

- Pipe diameter required = 61 cm (24 inches)[2]
- Average Dry Weather Flow (ADWF) = 0.066 m^3/s (1.5 mgd)[6]
- New population served by 0.11 m^3/s (2.5 mgd) treatment plant = 20,000 people[7]
- Total length of sewer pipe required = 140 200 metres (460,000 feet)

1/ From pipe size distribution for Sacramento County sewer system.

2/ From EPA Report MCD - 38 (11).

3/ National average cost in January 1978 dollars.

4/ Adjusted to California construction cost index of 1.14 and updated to 1979 EPA construction cost index of 1.12.

5/ Seven percent interest and 50-year life.

6/ From flow relationship of $\frac{\text{ADWF}}{\text{design flow}} = \frac{75}{125} \times 0.11 m^3/s = 0.066 m^3/s (2.5 mgd)$

7/ $\frac{\text{ADWF}}{\text{unit indoor water use}} = \frac{0.066 m^3/s}{3.3 \times 10^{-6} m^3/s \text{ per capita}} = 20,000$ people.

TABLE 25. SAMPLE CALCULATION FOR SEWER PIPE CAPITAL COST WITH REDUCTION IN INDOOR WATER USE, CASE I

1 Old Pipe[1] Size cm (inches)	2 New Pipe[2] Size cm (inches)	3 Length[1] m (feet)	4 Unit Pipe[3] Cost \$/m (\$/ft)	5 Pipe[4] Cost \$1,000 Col. 3 x Col. 4	6 Adjusted[5] Pipe Cost \$1,000	7 Equivalent[6] Annual Cost \$1,000
15.2 (6)	15.2 (6)	94 920 (311,420)	79 (24)	7,470		
20.3 (8)	15.2 (6)	22 570 (74,060)	79 (24)	1,777		
25.4 (10)	20.3 (8)	7 150 (23,460)	141 (43)	1,010		
30.5 (12)	25.4 (10)	5 190 (17,020)	154 (47)	800		
38.1 (15)	30.5 (12)	4 350 (14,260)	194 (59)	840		
45.7 (18)	38.1 (15)	2 660 (8,740)	240 (73)	635		
53.3 (21)	45.7 (18)	2 100 (6,900)	308 (94)	650		
61.0 (24)	53.3 (21)	1 260 (4,140)	387 (118)	490		
		140 200 (460,000)		13,667	17,450	1,265

NOTE: This sample calculation pertains to a corresponding treatment plant size of 0.11 m^3/s (2.5 mgd).

1/ From Table 24.
2/ From Table 23.
3/ From EPA Report MCD-38 (11).
4/ National Average Cost in January 1978 Dollars.
5/ Adjusted to California Construction Cost Index of 1.14 and updated to 1979 EPA Construction Cost Index of 1.12.
6/ 7 Percent Interest and 50-Year Life (13).

TABLE 26. SEWER LINE CAPITAL COST SAVINGS, CASE I

Corresponding Treatment Plant Size m^3/s (mgd)	Equivalent[1] Annual Capital Cost in 1979 Dollars (in $1,000)	Percent Reduction in Overall Community Indoor Water Use	Equivalent[1] Annual Capital Cost Savings (in $1,000)	(in percent)
0.04 (0.8)	430	10 - 35	60	14
0.11 (2.5)	1,470	10 - 35	205	14
0.55 (12.5)	8,860	10-35	1,420	16
1.10 (25)	18,630	10	2,875	15
		20 - 35	2,945	16
2.19 (50)	35,660	10	5,195	15
		20 - 35	5,480	15

[1] 7% interest and 50-year life (13).

TABLE 27. PERCENT SAVINGS IN O&M COST DUE TO WASTEWATER FLOW REDUCTIONS

Percent Overall Reduction in Community Indoor Water Use	New Sewer System Percent Flow Reduction	New Sewer System Percent O & M Cost Reduction	Existing Sewer System Percent Flow Reduction	Existing Sewer System Percent O & M Cost Reduction
10	31.0	1.5	4.8	0
20	35.0	1.8	16.3	0.5
30	37.5	2.0	28.1	1.3
35	39.0	2.1	34.0	1.7

TABLE 28. O&M COST SAVINGS FOR NEW SEWER SYSTEMS, CASE I

1	2	3	4	5	6	7
Corresponding Treatment Plant Size m^3/s (mgd)	Average ADWF for New Sewer System Over 20 Year Period m^3/s (mgd)	Population Served[1]	Annual[2] O&M Cost (in $1,000)	Percent Overall Reduction in Community Indoor Water Use	Annual O&M Cost Savings	
					(in Percent)	(in $1,000)[3]
0.04 (0.8)	0.01 (0.24)	3,200	23	10	1.5	0
				20	1.8	0
				30	2.0	0
				35	2.1	0
0.11 (2.5)	0.03 (0.75)	10,000	71	10	1.5	1
				20	1.8	1
				30	2.0	1
				35	2.1	1
0.55 (12.5)	0.16 (3.75)	50,000	353	10	1.5	5
				20	1.8	6
				30	2.0	7
				35	2.1	7
1.10 (25)	0.33 (7.5)	100,000	705	10	1.5	11
				20	1.8	13
				30	2.0	14
				35	2.1	15
2.19 (50)	0.66 (15)	200,000	1,410	10	1.5	21
				20	1.8	25
				30	2.0	28
				35	2.1	30

[1] Col. 2 ÷ 3.29×10^{-6} m^3/s/capita (75 gal/capita/day)

[2] Col. 3 x $7.05

[3] Col. 4 x Col. 6.

TABLE 29. O&M COST SAVINGS FOR EXISTING SEWER SYSTEM, CASE I

Corresponding Treatment Plant Size m^3/s (mgd)	Average ADWF for new Sewer System Over 20 Year Period m^3/s (mgd)	Population[1] Served	Annual[2] O&M Cost (in $1,000)	Percent Overall Reduction in Community Indoor Water Use	Annual O&M Cost Savings	
					(in percent)	(in $1,000)[3]
0.04 (0.8)	0.08 (1.85)	24,700	174	10	0	0
				20	0.5	1
				30	1.3	2
				35	1.7	3
0.11 (2.5)	0.25 (5.77)	76,900	542	10	0	0
				20	0.5	3
				30	1.3	7
				35	1.7	9
0.55 (12.5)	1.26 (28.8)	384,000	2,707	10	0	0
				20	0.5	14
				30	1.3	35
				35	1.7	46
1.10 (25)	2.53 (57.7)	769,300	5,424	10	0	0
				20	0.5	27
				30	1.3	71
				35	1.7	92
2.19 (50)	5.06 (115.4)	1,538,700	10,848	10	0	0
				20	0.5	54
				30	1.3	141
				35	1.7	184

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[1] Col. 2 ÷ 3.29×10^{-6} m^3/s capita (75 gal/capita/day)
[2] Col. 3 x $7.05
[3] Col. 4 x Col. 6

TABLE 30. COMBINED O & M COST SAVINGS FOR NEW AND EXISTING SEWER SYSTEMS, CASE I

Corresponding Treatment Plant Size m^3/s (mgd)	Percent Overall Reduction in Community Indoor Water Use	Annual O & M Cost Savings (in $1,000)		
		New Sewer System	Existing Sewer System	Total[1]
0.04 (0.8)	10	0	0	0
	20	0	1	0
	30	0	2	0
	35	0	3	0
0.11 (2.5)	10	1	0	0
	20	1	3	5
	30	1	7	10
	35	1	9	10
0.55 (12.5)	10	5	0	5
	20	6	14	20
	30	7	35	40
	35	7	46	55
1.10 (25)	10	11	0	10
	20	13	27	40
	30	14	71	85
	35	15	92	105
2.19 (50)	10	21	0	20
	20	25	54	80
	30	28	141	170
	35	30	184	215

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[1] Rounded to nearest $5,000.

TABLE 31. SUMMARY OF ANNUAL WATER CONSERVATION BENEFITS AT 10 PERCENT REDUCTION IN INDOOR WATER USE, CASE I (in $1,000)

Sewage Treatment Plant Design Flow m^3/s (mgd)	Energy Benefits			Water Supply Benefits	STP Capital Cost Savings	Collection System Cost Savings		Gross Benefits
	Hot Water Heating	Local Systems	Total			Capital	O&M	
0.04 (0.8	132	2	135	30	35	60	0	260
0.11 (2.5)	411	6	415	100	80	205	0	800
0.55 (12.5)	2,056	31	2,085	500	290	1,420	5	4,300
1.10 (25)	4,116	62	4,180	1,000	605	2,875	10	8,670
2.19 (50)	8,232	125	8,355	1,995	1,115	5,195	20	16,680

TABLE 32. SUMMARY OF ANNUAL WATER CONSERVATION BENEFITS AT 20 PERCENT REDUCTION IN INDOOR WATER USE, CASE I (in $1,000)

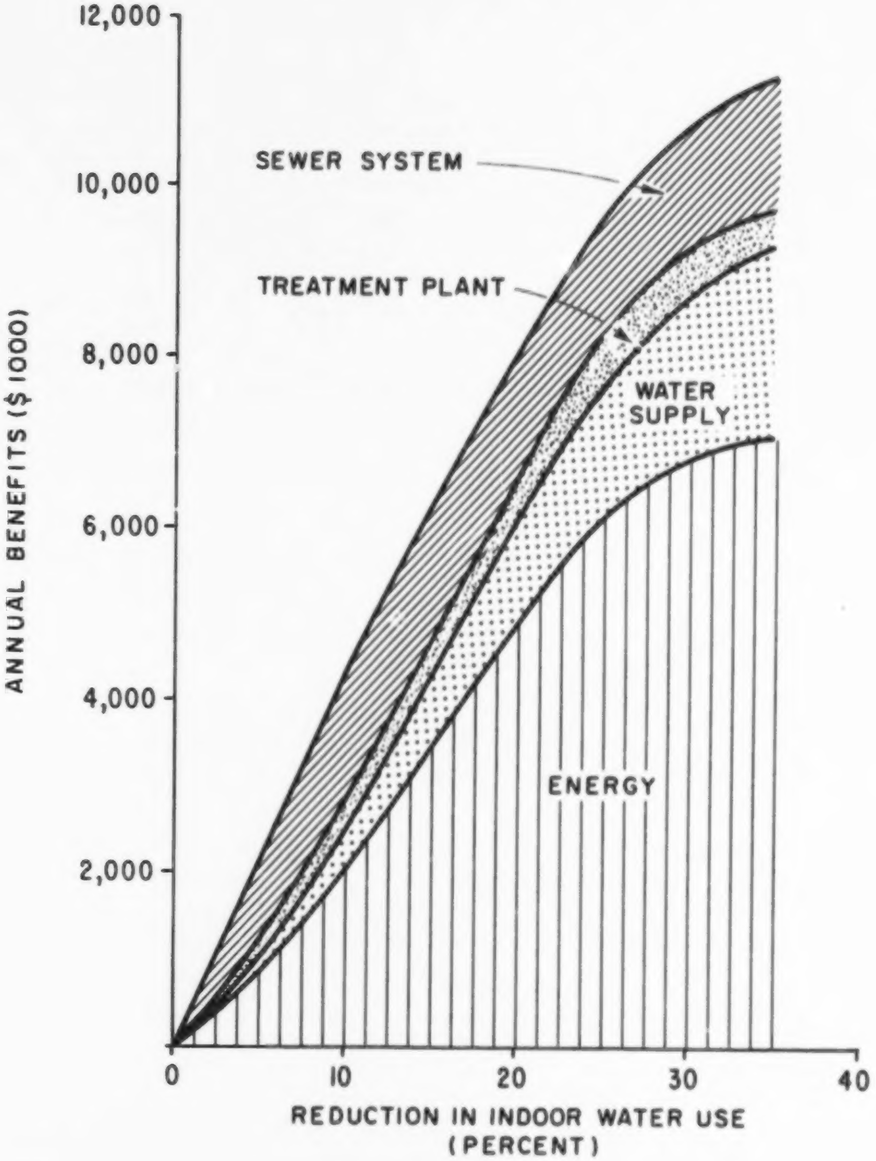
Sewage Treatment Plant Design Flow m^3/s (mgd)	Energy Benefits			Water Supply Benefits	STP Capital Cost Savings	Collection System Cost Savings		Gross Benefits
	Hot Water Heating	Local Systems	Total			Capital	O&M	
0.04 (0.8)	312	5	315	75	60	60	0	510
0.11 (2.5)	972	15	985	235	140	205	5	1,570
0.55 (12.5)	4,852	73	4,925	1,175	530	1,420	20	8,070
1.10 (25)	9,718	147	9,865	2,360	1,100	2,945	40	16,310
2.19 (50)	19,437	294	19,730	4,715	2,035	5,480	80	32,040

TABLE 33. SUMMARY OF ANNUAL WATER CONSERVATION BENEFITS AT 30 PERCENT REDUCTION IN INDOOR WATER USE, CASE I (in $1,000)

Sewage Treatment Plant Design Flow m^3/s (mgd)	Energy Benefits			Water Supply Benefits	STP Capital Cost Savings	Collection System Cost Savings		Gross Benefits
	Hot Water Heating	Local Systems	Total			Capital	O&M	
0.04 (0.8)	431	7	440	120	60	60	0	680
0.11 (2.5)	1,345	23	1,370	275	145	205	10	2,005
0.55 (12.5)	6,714	116	6,830	1,860	540	1,420	40	10,690
1.10 (25)	13,448	233	13,680	2,730	1,125	2,945	85	20,565
2.19 (50)	26,897	465	27,360	7,460	2,085	5,480	170	42,555

TABLE 34. SUMMARY OF ANNUAL WATER CONSERVATION BENEFITS AT 35 PERCENT REDUCTION IN INDOOR WATER USE, CASE I (in $1,000)

Sewage Treatment Plant Design Flow m^3/s (mgd)	Energy Benefits			Water Supply Benefits	STP Capital Cost Savings	Collection System Cost Savings		Gross Benefits
	Hot Water Heating	Local Systems	Total			Capital	O&M	
0.04 (0.8)	437	9	445	140	60	60	0	705
0.11 (2.5)	1,366	28	1,395	440	145	205	10	2,195
0.55 (12.5)	6,900	138	7,040	2,205	540	1,420	55	11,260
1.10 (25)	13,658	276	13,935	4,420	1,125	2,945	105	22,530
2.19 (50)	27,317	551	27,870	8,835	2,085	5,480	215	44,485



EXAMPLE: 0.55 m^3/s (12.5 mgd) Treatment Plant Size.

Figure 10. Annual water conservation benefits, Case I.

TABLE 35. EXPECTED REDUCTIONS IN PERCENT OF INDOOR WATER USE, CASE II

		Scenario 1 Potential		Scenario 2 Moderate Water Conservation Effort		Scenario 3 Minimal Water Conservation Effort	
Water Conservation Measures	Potential Savings	Percent[1] Installing	Expected Reductions	Percent Installing	Expected Reductions	Percent Installing	Expected Reductions
Toilet	14[3]	100	14	100	14	100	14
Shower[2]	12[4]	100	12	100	12	100	12
Faucet[2]	2[5]	100	2	100	2	100	2
Pressure Reducing Valve	4[5]	100	4	10	0.4	0	0
Hot Water Pipe Insulation	2[4]	100	2	50	1	0	0
Clothes Washer[2]	5[5,6]	100	5	100	5	50	2.5
Dish Washer[2]	0.5[7]	100	0.5	100	0.5	50	0.2
Hot Water Savings	TOTAL		21.5		20.5		16.7
Hot and Cold Water Savings	TOTAL (Rounded)		39.5 (40)		34.9 (35)		30.7 (30)

[1] Percent of households installing water conservation measures.

[2] Measures generating hot water energy.

(continued)

FOOTNOTES FOR TABLE 35 (continued)

3/ Use volume of conventional toilets = 19.76 litres (5.22 gallons). California State Department of Water Resources (DWR) Bulletin 191, Appendix G (6).
Low-flush toilets = 13.2 litres (3.5 gallons) per flush mandatory.

$$\text{Savings} = \frac{6.51 \text{ litres } (1.72 \text{ gal})}{19.76 \text{ litres } (5.22 \text{ gal})} = 33\% \text{ per flush.}$$

Toilet use = 42% indoor use. Therefore, 33% times 42% = 14% of indoor use saved by low-flush toilets.

4/ Average flow of conventional showerheads at 310 kilopascals (45 psi) = 31.61 litres per minute (8.35 gpm). DWR Bulletin 191, Appendix G (6).
Flow of low-flow showerheads = 11.36 litres per minute (3 gpm) (mandatory).

$$\text{Savings} = \frac{20.25 \text{ litres/min } (5.35 \text{ gal/min})}{31.61 \text{ litres/min } (8.35 \text{ gal/min})} = 64\% \text{ per shower.}$$

Daily use per household based on data in DWR Bulletin 206, Appendix (8):
Shower = 2.6 times
Bathtub = 1.8 times.
Volume of shower use = 31.61 litres/min (8.35 gpm) x 6 min x 2.6 = 492 litres (130 gal)
Volume of tub use = 189 litres (50 gal) x 1.8 = 341 litres (90 gal)
TOTAL 833 litres (220 gal)

Bathing use = 32% of indoor use. Therefore, shower savings =

$$64\% \text{ savings} \times \frac{492 \text{ litres } (130 \text{ gal})}{833 \text{ litres } (220 \text{ gal})} \times 32\% = 12\% \text{ of indoor use.}$$

5/ DWR Bulletin 198 (5).

6/ Assumes that all new machines manufactured in the next 20 years will employ a water-saving feature. While not all households will own washers, the assumption is that they will be using water-saving machines at the laundromat.

7/ Assumes that new dishwashers manufactured in the next 20 years will employ a water-saving feature. Twenty-four percent own dishwashers. DWR Bulletin 198 (5).

TABLE 36. AMOUNT OF WATER SAVINGS DUE TO WATER CONSERVATION, CASE II

Treatment Plant Design Flow m^3/s (mgd)	ADWF 1/ New Bldg Construction m^3/s (mgd)	Avg ADWF 2/ New Bldg Construction Over 20-year period m^3/s (mgd)	Percent Reduction in Indoor Water Use	Total Water 3/ Saved dam^3 (ac-ft)	Hot Water 4/ Saved dam^3 (ac-ft)
0.04 (0.8)	0.02 (0.48)	0.01 (0.24)	30	199 (161)	110 (89)
			35	232 (188)	199 (161)
			40	265 (215)	146 (118)
0.11 (12.5)	0.07 (1.5)	0.03 (0.75)	30	622 (504)	342 (277)
			35	725 (588)	435 (353)
			40	829 (672)	456 (370)
0.55 (12.5)	0.33 (7.5)	0.16 (3.75)	30	3 108 (2,520)	1 710 (1,386)
			35	3 626 (2,940)	2 176 (1,764)
			40	4 145 (3,360)	2 280 (1,848)
1.10 (25)	0.66 (15)	0.33 (7.5)	30	6 217 (5,040)	3 419 (2,772)
			35	7 253 (5,880)	4 352 (3,528)
			40	8 289 (6,720)	4 559 (3,696)
2.19 (50)	1.31 (30)	0.66 (15)	30	12 434 (10,080)	6 839 (5,544)
			35	14 506 (11,760)	8 704 (7,056)
			40	16 578 (13,440)	9 118 (7,392)

1/ Treatment plant design flow x $\frac{75}{125}$
2/ Col. 2 ÷ 2
3/ Col. 3 x Col. 4
4/ Col. 5 x percent hot water savings

TABLE 37. WATER SUPPLY BENEFITS, CASE II

Treatment Plant Design Flow m^3/s (mgd)	Annual Water Supply Benefits at Various Levels of Indoor Water Use Reductions (in $1,000)		
	30%	35%	40%
0.04 (0.8)	15	15	20
0.11 (2.5)	45	50	60
0.55 (12.5)	220	255	295
1.10 (25)	440	515	590
2.19 (50)	880	1,030	1,175

TABLE 38. ANNUAL ENERGY BENEFITS, CASE II
(in $1,000)

Treatment Plant Size m^3/s (mgd)	Percent Reduction in Indoor Use	Water Heating	Local Systems	Total[1/]
0.04 (0.8)	30	40	1	40
0.11 (2.5)	30	125	3	130
0.55 (12.5)	30	625	14	640
1.10 (25)	30	1,250	28	1,280
2.19 (50)	30	2,499	55	2,555
0.04 (0.8)	35	51	1	50
0.11 (2.5)	35	160	3	165
0.55 (12.5)	35	795	16	810
1.10 (25)	35	1,590	32	1,620
2.19 (50)	35	3,181	64	3,245
0.04 (0.8)	40	53	1	55
0.11 (2.5)	40	167	4	170
0.55 (12.5)	40	833	18	850
1.10 (25)	40	1,666	37	1,703
2.19 (50)	40	3,332	73	3,405

[1/] Rounded to nearest $5,000.

TABLE 39. CAPITAL COST SAVINGS FOR SECONDARY TREATMENT PLANTS, CASE II

Treatment Plant Size in m^3/s (mgd)	Equiv. Annual Capital Cost1/ (in $1,000)		Annual Capital Cost Savings for Treatment Plants (in $1,000)		
		Flow Reduction =	30%	35%	40%
		Cost Reduction =	6%	7%	8%
0.04 (0.8)	280		15	20	20
0.11 (2.5)	660		40	45	50
0.55 (12.5)	2,460		150	170	195
1.10 (25)	5,110		305	360	410
2.19 (50)	9,470		570	665	760

1/ Cost derived from equation, cost = $kQ^{0.89}$, adjusted from national average to California prices, adjusted to reflect 1979 dollars (EPA cost index), and applying 7% interest and 25 years of service life(3).

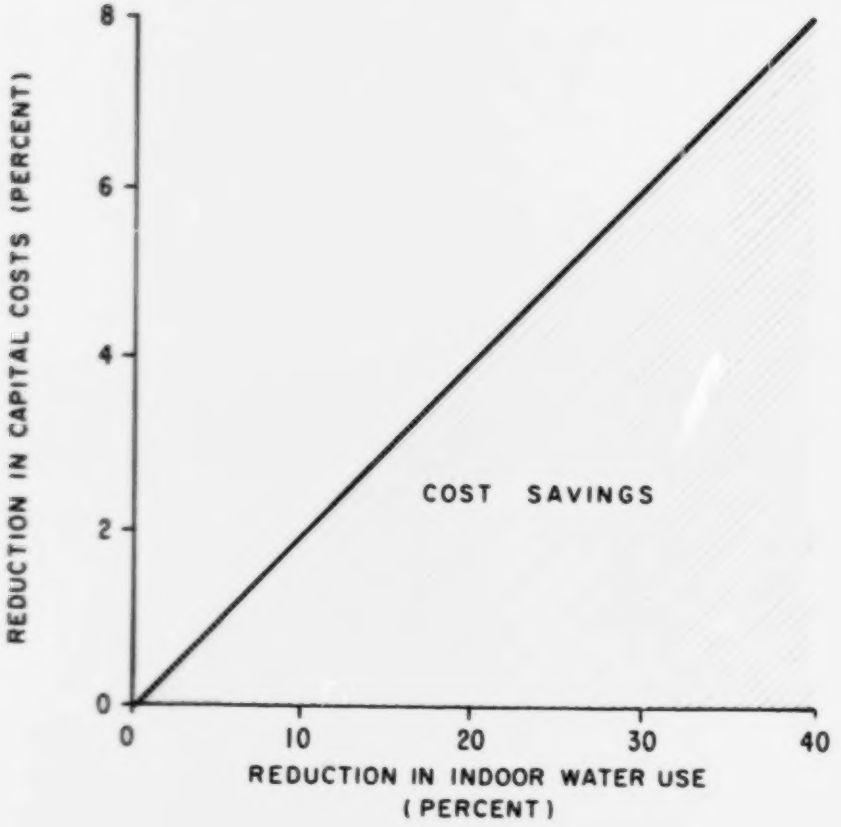


Figure 11. Reduction in capital cost of secondary treatment plants, Case II.

TABLE 40. SEWER LINE CAPITAL COST SAVINGS, CASE II

Corresponding Treatment Plant Size m^3/s (mgd)	Capital Cost, 1979 dollars (in $1,000)	Percent Flow Reduction	Equivalent Annual Cost Savings[1] (in $1,000)
0.04 (0.8)	5,890	30 - 40	20
0.11 (2.5)	20,340	30 - 40	75
0.55 (12.5)	122,220	30 - 40	775
1.10 (25)	257,050	30 35 - 40	1,690 1,760
2.19 (50)	492,170	30 35 - 40	2,750 3,035

[1] 7% interest and 50-year life (3).

TABLE 41. ANNUAL O & M COST SAVINGS IN SEWER SYSTEMS, CASE II

1	2	3	4	5	6	
Corresponding Treatment Plant Size m^3/s (mgd)	Percent Reduction In Indoor Water Use	Average[1] ADWF ≅ Indoor Water Use Over 20-Year Period m^3/s (mgd)	Population[2] Served	Annual[3] O & M Cost (in $1,000)	O & M Cost Savings	
					Percent	$1,000[4]
0.04	30	0.011	3,200	23	0.5	0
(0.8)	35	(0.24)			1.0	0
	40				1.5	0
0.11	30	0.033	10,000	71	0.5	0
(2.5)	35	(0.75)			1.0	0
	40				1.5	0
0.55	30	0.16	50,000	353	0.5	5
(12.5)	35	(3.75)			1.0	5
	40				1.5	5
1.10	30	0.33	100,000	705	0.5	5
(25)	35	(7.5)			1.0	10
	40				1.5	10
2.19	30	0.66	200,000	1,410	0.5	15
(50)	35	(15)			1.0	15
	40				1.5	20

[1] Col. 1 x $\frac{75}{125} \div 2$

[2] Col. 3 ÷ $3.29 \times 10^{-6} m^3/s$/capita (75 gal./capita/day)

[3] Col. 4 x $7.05/capita

[4] Rounded to nearest $5,000

TABLE 42. SUMMARY OF ANNUAL WATER CONSERVATION BENEFITS AT 30 PERCENT REDUCTION IN INDOOR USE, CASE II

(in $1,000)

Treatment Plant Design Flow m^3/s(mgd)	Energy Benefits			Water Supply Benefits	Treatment Plant Capital Cost Savings	Sewer System Cost Savings		Gross Benefits
	Water Heating	Local Systems	Total 1/			Capital	O&M	
0.04 (0.8)	40	1	40	15	15	20	0	90
0.11 (2.5)	125	3	130	45	40	75	0	290
0.55 (12.5)	625	14	640	220	150	775	5	1,790
1.10 (25)	1,250	28	1,280	440	305	1,690	10	3,725
2.19 (50)	2,499	55	2,555	880	570	2,750	20	6,775

1/ Values rounded to nearest $5,000.

TABLE 43. SUMMARY OF ANNUAL WATER CONSERVATION BENEFITS AT 35 PERCENT REDUCTION IN INDOOR USE, CASE II
(in $1,000)

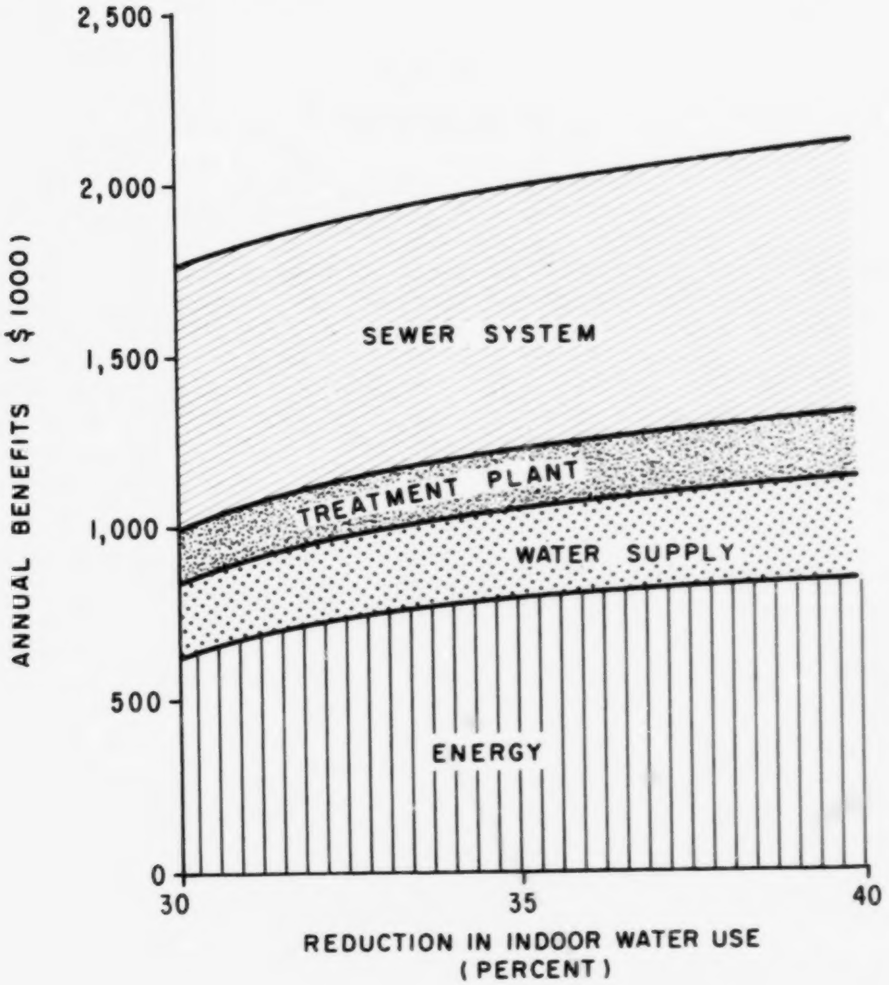
Treatment Plant Design Flow m^3/s (mgd)	Energy Benefits			Water Supply Benefits	Treatment Plant Capital Cost Savings	Sewer System Cost Savings		Gross Benefits
	Water Heating	Local Systems	Total1/			Capital	O&M	
0.04 (0.8)	51	1	50	15	20	20	0	105
0.11 (2.5)	160	3	165	50	45	75	0	335
0.55 (12.5)	795	16	810	255	170	775	5	2,015
1.10 (25)	1,590	32	1,620	515	360	1,760	15	4,270
2.19 (50)	3,181	64	3,245	1,030	665	3,035	25	8,000

1/ Values rounded to nearest $5,000.

TABLE 44. SUMMARY OF ANNUAL WATER CONSERVATION BENEFITS AT 40 PERCENT REDUCTION IN INDOOR USE, CASE II (in $1,000)

Design Flow m^3/s (mgd)	Energy Benefits			Water Supply Benefits	Treatment Plant Capital Cost Savings	Sewer System Cost Savings		Gross Benefits
	Water Heating	Local Systems	Total 1/			Capital	O&M	
0.04 (0.8)	53	1	55	20	20	20	0	115
0.11 (2.5)	167	4	170	60	50	75	0	355
0.55 (12.5)	833	18	850	295	195	775	10	2,125
1.10 (25)	1,666	37	1,703	590	410	1,760	15	4,478
2.19 (50)	3,332	73	3,405	1,175	760	3,035	30	8,405

1/ Values rounded to nearest $5,000.



EXAMPLE: 0.55 m^3/s (12.5 mgd) Treatment Plant Size.

Figure 12. Annual water conservation benefits, Case II.

SECTION 6

WATER CONSERVATION COSTS

Basis of Analysis

The negative effects, or costs, of water conservation measures and their impact on wastewater reuse will be examined in this section. The cost analysis was based on the following approach:

- Select conditions for analysis. This involves a 20-year period of analysis and two cases -- Case I and Case II -- for which new sewer collection and treatment facilities are commonly constructed to serve new population growth as was done in Section 5, "Water Conservation Benefits".

- Estimate the cost of various scenarios of water conservation measures at different levels of water conservation efforts ranging from minimal to potential. The cost of water conservation measures is estimated in terms of annual unit cost per household. The number of households served by the various sizes of wastewater systems are multiplied by the annual unit cost to determine the total cost of the measures.

- Assess the impact on wastewater reuse. Three major uses of wastewater, namely, crop irrigation, landscape irrigation, and industrial use, are examined to determine how much they are affected by changes in wastewater quality as a result of flow reduction.

Case I -- New Wastewater Facilities Constructed as Additions to Existing Facilities

Cost of Water Conservation Measures

In Section 5, "Water Conservation Benefits", various scenarios of water conservation measures to achieve different levels of indoor water use reductions were examined. The scenarios showed us that the following levels of indoor use reduction could be achieved:

Scenario	Percent Reduction in Indoor Use	Water Conservation Effort
1	35	Potential
2	25	Moderate
3	10	Minimal

For scenarios 1 and 2, the measures to reduce indoor water use include low-water-using tank toilet, shower, and faucet fixtures; pressure-reducing valves; insulated hot water pipes; clothes and dishwashers with water-saving features; and educational and advertising campaigns. Scenario 3 includes the same measures except pressure-reducing valves and insulated hot water pipes. The unit annual cost of these measures and the description of conditions assumed to estimate this cost are contained in Table 45. The annual unit cost of the water conservation measures is also depicted in Figure 13.

The annual cost of water conservation measures was determined by multiplying the number of households served by the wastwater system by the unit cost (see Table 46).

Impact on Wastewater Reuse

The reuse of wastewater for beneficial use is an increasingly important water conservation measure being taken in California. Reclaimed wastewater is presently being used in a variety of ways. A reduction in wastewater flow would change the quality of the water that is reused, which in turn could affect the uses to which such water can be put. Crop and landscape irrigation uses constitute about 74% of the wastewater currently reused (16) and projected to be reclaimed by 1984,[1/] and thus are the primary uses considered for analysis. The remaining projected uses[1/] are industrial (19%), ground water recharge (5%), and other uses (2%). The use of reclaimed water specifically for ground water recharge involves numerous variables and is a complex subject that is outside the scope of this study. In California, ground water recharge with reclaimed wastewater is allowed only on a case-by-case basis.

In general, salt concentration is the most significant factor likely to affect both irrigation and industrial uses. It is recognized that high values of boron concentration and sodium absorption ratios in the sewage effluent would also cause problems for crop irrigation. However, these problems were not included in the analysis because they are not widespread in California. Also, the curtailment of supply due to wastewater flow reduction is not normally a problem because the amount reclaimed is usually only a fraction of the wastewater produced. In 1977, the amount reused in California was about 6%[2/] of the wastewater production.

[1/] From unpublished data by California State Water Resources Control Board, Office of Water Recycling, 1979.

[2/] From California Department of Health Services Report, 1978 (16) and California Department of Water Resources unpublished data, Division of Planning, Water Reclamation and Supply Branch, 1979.

Currently, wastewater is largely used to irrigate the following crops and landscapes (16):

Crop

Hay (alfalfa)	Citrus Orchard
Pasture	Deciduous orchard
Corn	Cotton
Grape (vineyard)	Barley

Landscape (largely turfgrass)

Golf course	Schoolgrounds
Parks	Playgrounds

To what extent does increased salt concentration affect these uses? The approach used in answering this question in quantified terms is to examine the effect of incremental increase in salt concentration on crop yield and the survival rate of the landscape. Crop loss due to lower yield will be determined in the case of crop irrigation. For landscape irrigation, the cost of replacing the turf that does not survive will be the primary consideration. The value of the crop loss and the cost of turf replacement can be considered as a fair reduction in the price for reclaimed water that the user would pay to compensate for these losses.

Impact on Crop Irrigation. The degree of salt tolerance differs with the kinds of crops grown. For instance, citrus and deciduous orchards are much more sensitive to salt concentration than cotton or barley. One way of measuring the crop tolerance to salt is to determine the crop yield at different levels of salt concentration in the irrigated water. As salt concentrations are increased, the crop tends to reduce its yield (17) as shown in Figure 14. The salt concentration is expressed in terms of electrical conductivity of the irrigation water. It is also expressed in approximate TDS values by multiplying the EC values by 640.

Cotton and barley as shown in Figure 14 have a high tolerance to salt and are not considered to be affected by the range of incremental increase in TDS expected from reductions in flow. In assessing the effect on other crops, the following assumptions were made because adequate TDS data from the treatment plants surveyed or other plants were not available.

- Domestic use causes a salt pick-up of 300 mg/l[1/] in the water used.
- The quality of the effluent applied to the crops is such that any incremental increase in TDS will begin to cause a reduction in crop yield.

[1/] State Water Pollution Control Board, Publication No. 9 (18).

The incremental TDS increase attributable to reductions in indoor use are estimated as follows:

Percent Reduction in Indoor Use	TDS Pick-up Due to Domestic Use with Water Conservation (in mg/l)	Incremental TDS Increase (in mg/l)
10	$\frac{300}{0.9}$ = 333	333-300 = 33
20	375	75
30	429	129
35	462	162

Based on values from Figure 14, the amounts of crop yield reduction can be approximated at different levels of incremental TDS increase and are shown in Figure 15. Because of the lack of TDS data, Figure 15 reflects the assumption that the effluent applied to each crop has a TDS level such that any incremental TDS increase affects crop yield.

The value of the crop loss was determined by analyzing the crop yield reduction along with the following considerations:

- Identification of crops by specific regions in counties.
- Determination of applied water by specific regions in counties.
- Determination of acreage of crops using reclaimed water.
- Determination of value of crops grown.

A summary for the determination of the value of unit crop loss ($/dam^3) is shown in Table 47 and depicted in Figure 16. Because one can only speculate about the specific crops that would use reclaimed water in the future, it was assumed that the current pattern of crop irrigation would continue.

The amount of crop loss varied considerably depending on the type of crop using the reclaimed water. For example, at 30% flow reduction, the annual crop loss ranged from $1.40/dam^3 ($1.73/ac-ft) for hay to $26.09/dam^3 ($32.18/ac-ft) for citrus orchard (see Table 47 and Figure 16). However, to depict a condition characterizing average statewide conditions, it was necessary to adjust this range of crop loss values in proportion to the acreage for each crop using reclaimed water (weighted average). The weighted average of the crop loss was found to be not very significant, with values ranging from $0.44/dam^3 ($0.54/ac-ft) to $2.23/dam^3 ($2.75/ac-ft) at 10% and 35% reduction in indoor use, respectively (see Table 47). The amount of water projected for crop irrigation constitutes about 9%[1/] of wastewater production

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[1/] From unpublished data from California State Water Resources Control Board, Office of Water Recycling, and California Department of Water Resources, Division of Planning, Water Reclamation and Supply Branch, 1979.

at the mid-point of the next 20-year period. When this projection is taken into account, the crop loss is minimal and represents the average impact on a statewide basis. This can be illustrated with the following example for Case I:

> For a treatment plant size of 0.55 m^3/s (12.5 mgd), the average dry weather flow (ADWF), for new and existing building constructions, at the mid-point of the next 20-year period of analysis is 1.42 m^3/s (32.6 mgd) (see Table 17). The average wastewater flow
>
> $= 1.42\ m^3/s \times \frac{100}{75} = 1.89\ m^3/s$ (43.2 mgd).
>
> The amount of water reused
>
> $= (1.89\ m^3/s)$ (9% reuse) $= 0.17\ m^3/s$ (3.9 mgd)
>
> $= 5\ 665\ dam^3/yr$ (4,350 ac-ft/yr).
>
> Amount of crop loss, at 30% flow reduction, for example
>
> $= (5\ 365\ dam^3/yr)\ (\$1.73/dam^3) = \$9,300/yr$.
>
> This compares with a gross benefit of $10,905,000/yr (see Table 33) or less than 1/10 of 1%.

Reductions in wastewater flow would increase the concentrations of nutrients and could be beneficial to the crops. This would tend to offset the crop loss due to higher TDS concentrations but no attempt was made to quantify this effect.

The reader should keep in mind that the impact on specific reuse projects could vary measurably on a case-by-case basis. For example, in a case where the water reused has an incremental mineral increase that is excessively high and is applied to an orchard, the impact on crop loss would be much greater than the average values shown.

Impact on Landscape Irrigation. For turfgrass, the primary landscape for golf courses, parks, schoolgrounds, and playgrounds, the survival rate rather than the yield response as forage was considered to be important (21). The kinds of grass commonly used for turf were found to have good survival rates using irrigation water with a high salt concentration. The average survival rate for four kinds of common turfgrass was shown to be about 98% at a TDS concentration as high as 5 000 mg/l (see Figure 17). It is concluded that the magnitude of incremental increase in salt concentration resulting from reduction in indoor water use has little impact on turfgrass irrigation.

Impact on Industrial Uses. One way of measuring the impact of water conservation on industrial uses is to estimate the cost of mitigating the incremental increase in salt concentration induced by water conservation. One method of mitigation is to desalt a portion of the reclaimed wastewater and then blend the desalted water with the effluent to attain the salt concentration prior to reduction in wastewater flow. This is discussed in greater detail in Section 8, "Penalty Costs".

Water conservation induced wastewaster flow reduction is not expected to cause an impact of any significance on industrial uses when compared to the overall benefits it would generate on a statewide basis. This can be illustrated by using the example discussed under crop irrigation as follows:

Treatment plant size = 0.55 m^3/s (12.5 mgd)

Average wastewater flow = 1.89 m^3/s (43.2 mgd).

The amount of water projected for industrial uses constitutes about 4%[1/] of wastewater production at the mid-point of the next 20-year period. The amount of water that would be reused for industrial uses

= (1.89 m^3/s) (4% reclamation) = 0.076 m^3/s (1.73 mgd)

= 2 385 dam^3/yr (1,935 ac-ft/yr)

Cost of desalting at 30% wastewater flow reduction, for example,

= (2 385 dam^3/yr) (\$31.20/dam^3)[2/] = \$74,400/yr.

This compares with a gross benefit of \$10,905,000/yr (see Table 33) or less than 1%.

Other Impacts

During the recent drought years when it was necessary to undertake many water conservation measures, there were no known cases of adverse impacts on the aquatic environment that were attributable to changes in water conditions brought about by reductions in indoor water use. However, the determination of the specific effects of water conservation induced wastewater flow reductions on the aquatic environment would entail a biological study and is considered outside the scope of this study. The San Diego Water Reclamation Agency is currently studying a related subject, the feasibility of using reclaimed water for the purpose of creating a live stream.

[1/] From unpublished data from California State Water Resources Control Board, Office of Water Recycling, and California Department of Water Resources, Division of Planning, Water Reclamation and Supply Branch, 1979.

[2/] Derivation of this cost is discussed later in Section 8, "Penalty Costs".

Case II - New Wastewater Facilities Constructed Independent of Existing Facilities

Cost of Water Conservation Measures

The annual unit cost of water conservation measures for the various scenarios and description of conditions assumed to estimate this cost are contained in Table 48. The annual cost of water conservation measures were determined by multiplying the number of households served by the wastewater system by the unit cost (see Table 49).

Impact on Wastewater Reuse

The discussions for Case I also apply to Case II and will not be repeated here. The main point is that water conservation has only minimal impact on wastewater reuse.

TABLE 45. UNIT COST OF WATER CONSERVATION MEASURES, CASE I

Water Conservation Measures	Existing Construction	New Construction	Annual Unit Cost (in $/household)
	Scenario 1 - Potential		
Toilet	Cost of material (mixture of toilet dams, plastic bottles, plastic bags) included. Installation cost by plumber included.	Toilet - No additional cost.	7.43[1]
Shower	Cost of material (showerheads and restrictors) included. Installation cost by plumber included.	Showerhead - No additional cost.	
Faucet	Cost of material (faucet aerators) included. Installation cost by plumber included.	Faucet - No additional cost.	
Pressure-Reducing Valve	Cost of material included. Installation cost by plumber included.	Cost of material included.	13.13[2]
Hot Water Pipe Insulation	Cost of material included. Installation cost by plumber included.	Cost of material included.	9.59[2]
Dishwasher/ Clothes Washer	No additional cost for water-saving feature of replacement appliances.	No additional cost.	0
Education/ Advertising	Cost included.	Cost included.	0.15[3]
		TOTAL	30.30

---

[1] Material costs are based on bid prices for the Department of Water Resources water conservation pilot projects in 1977 and updated to 1979 prices. All installation costs by plumbers were based on the current (1979) wage scale for plumbers. Annual unit cost reflects capital costs amortized at 7% interest and a 5-year life.

[2] Capital costs amortized at 7% interest and a 20-year life.

[3] Education cost based on current student education program for water conservation by DWR. Advertising cost based on DWR water conservation pilot program in San Diego in 1977 updated to 1979 dollars.

(continued)

TABLE 45 (continued)

Water Conservation Measures	Existing Construction	New Construction	Annual Unit Cost (in $/household)
	Scenario 2 - Moderate Water Conservation Effort		
Toilet	Cost of material (mixture of toilet dams, plastic bottles and plastic bags) included. No installation cost included.	Toilet - No additional cost.	3.74[1]
Shower	Cost of material (showerheads and restrictors) included. No installation cost included.	Showerhead - No additional cost.	
Faucet	Cost of material (faucet aerators) included. No installation cost included.	Faucet - No additional cost.	
Pressure-Reducing Valve	Cost of material included. Installation cost by plumber included.	Cost of material included.	9.01[2]
Hot Water Pipe Insulation	Cost of material included. Installation cost by plumber included.	Cost of material included.	0.65[2]
Dishwasher/ Clothes Washer	No additional cost for water-saving feature of replacement appliances.	No additional cost.	0
Education/ Advertising	Cost included.	Cost included.	0.15[3]
		TOTAL	13.55

---

[1] Material costs are based on bid prices for the Department of Water Resources water conservation pilot projects in 1977 and updated to 1979 prices. All installation costs by plumbers were based on the current (1979) wage scale for plumbers. Annual unit cost reflects capital costs amortized at 7% interest and a 5-year life.

[2] Capital costs amortized at 7% interest and a 20-year life.

[3] Education cost based on current student education program for water conservation by DWR. Advertising cost based on DWR water conservation pilot program in San Diego in 1977 updated to 1979 dollars.

(continued)

TABLE 45 (continued)

Water Conservation Measures	Existing Construction	New Construction	Annual Unit Cost (in $/household)
Scenario 3 - Minimal Water Conservation Effort			
Toilet	No retrofitting	Toilet - No additional cost.	0
Shower	Cost of material (showerheads and restrictors) included. No installation cost included.	Showerhead - No additional cost.	0.10[1]
Faucet	Cost of material (faucet aerator) included. No installation cost included.	Faucet - No additional cost.	
Dishwasher/ Clothes Washer	No additional cost for water-saving feature of replacement appliances.	No additional cost.	0
Education	Cost included.	Cost included.	0.10[3]
		TOTAL	0.20

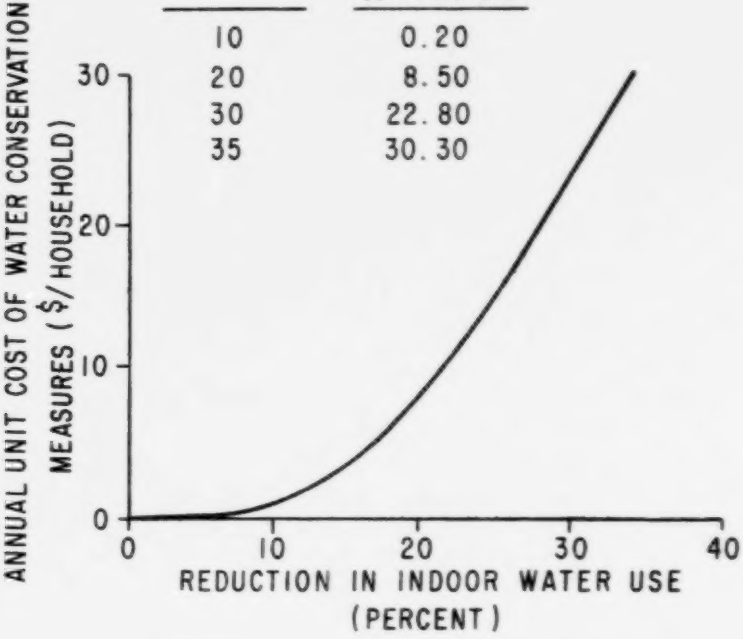
---

[1] Material costs are based on bid prices for the Department of Water Resources water conservation pilot projects in 1977 and updated to 1979 prices. All installation costs by plumbers were based on the current (1979) wage scale for plumbers. Annual unit cost reflects capital costs amortized at 7% interest and a 5-year life.

[2] Capital costs amortized at 7% interest and a 20-year life.

[3] Education cost based on current student education program for water conservation by DWR. Advertising cost based on DWR water conservation pilot program in San Diego in 1977 updated to 1979 dollars.

Percent Reduction In Indoor Water Use	Annual Unit Cost of Water Conservation Measures $/Household
10	0.20
20	8.50
30	22.80
35	30.30



Condition

- 20-year growth factor = 1.26
- Reflects mix of new and existing construction @ mid-point of 20-year period.

Figure 13. Annual unit cost of water conservation measures, Case I.

TABLE 46. ANNUAL COST OF WATER CONSERVATION MEASURES, CASE I

Treatment Plant Size m^3/s (mgd)	Indoor[1] Water Use New Bldg Construction m^3/s (mgd)	Indoor[2] Water Use Existing Bldg Construction m^3/s (mgd)	Total Indoor Water Use m^3/s (mgd)	Households[3] Served New Plus Existing Bldg Construction	Percent Reduction Indoor Water Use	Annual Unit Cost of Water Conservation Measures (in $ per household)	Annual Cost of Water Conservation Measures (in $1,000)
0.035 (0.8)	0.011 (0.24)	0.081 (1.85)	0.092 (2.09)	10,130	10	0.20	0
					20	8.50	85
					30	22.80	230
					35	30.30	305
0.11 (2.5)	0.03 (0.75)	0.25 (5.77)	0.29 (6.52)	31,610	10	0.20	5
					20	8.50	270
					30	22.80	720
					35	30.30	960
0.55 (12.5)	0.16 (3.75)	1.26 (28.85)	1.43 (32.60)	158,060	10	0.20	30
					20	8.50	1,345
					30	22.80	3,605
					35	30.30	4,790
1.10 (25)	0.33 (7.5)	2.53 (57.7)	2.86 (65.2)	316,120	10	0.20	65
					20	8.50	2,685
					30	22.80	7,210
					35	30.30	9,580
2.19 (50)	0.66 (15)	5.06 (115.4)	5.71 (130.4)	632,240	10	0.20	125
					20	8.50	5,375
					30	22.80	14,415
					35	30.30	19,155

---

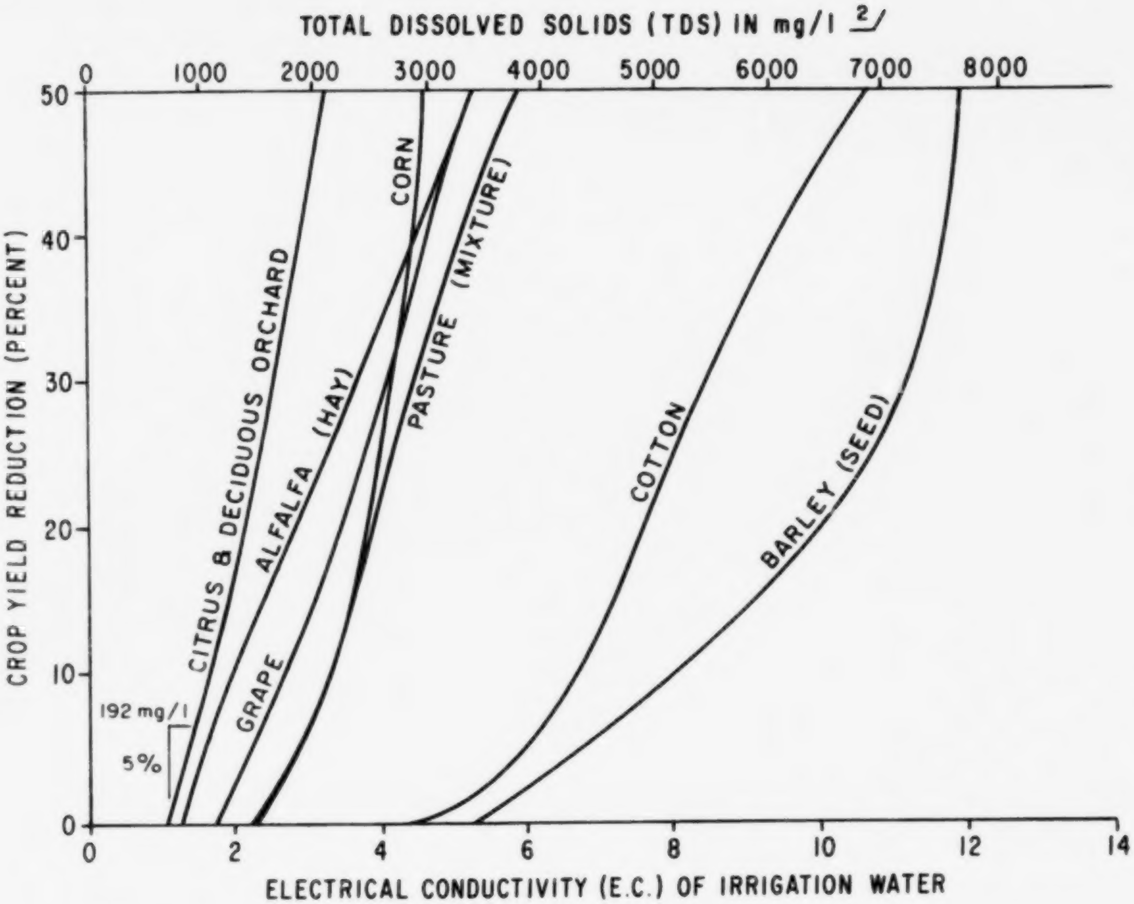
[1] Indoor water use ≅ ADWF.
Average ADWF of new construction ≅ (design flow) $\frac{(75\%)}{125\%} \div 2$ and represents ADWF at the mid-point of 20-year growth period.

[2] Population growth factor at mid-point of 20-year period = 1.13.
Then ADWF of existing construction =

$$\frac{\text{ADWF (of new construction at mid-point of 20-year period)}}{0.13}.$$

[3] Use indoor water use at $3.29 \times 10^{-6} m^3/s$/capita (75 gal/capita/day) and 2.75 persons per household. Total indoor use ≅ total ADWF.
Number of households =

$$\frac{\text{Total indoor use in } m^3/s}{(3.29 \times 10^{-6} m^3/s/\text{capita})(2.75)} \text{ or } \frac{\text{Total indoor use in mgd}}{(75 \text{ gal/capita/day})(2.75)}.$$



[1] "Guidelines For Interpretation of Quality of Water For Irrigation", May 1974, Univ. of Calif., Agricultural Extension (17). Soil leaching requirements are reflected in the values.

[2] Approximate conversion, 1 E.C. mmho/cm = 640 mg/l.

Figure 14. Crop salt tolerance.[1]

NOTE: This chart portrays a condition whereby the effluent applied to each crop has a TDS level such that any incremental increase in TDS will begin to cause a crop yield decrement.

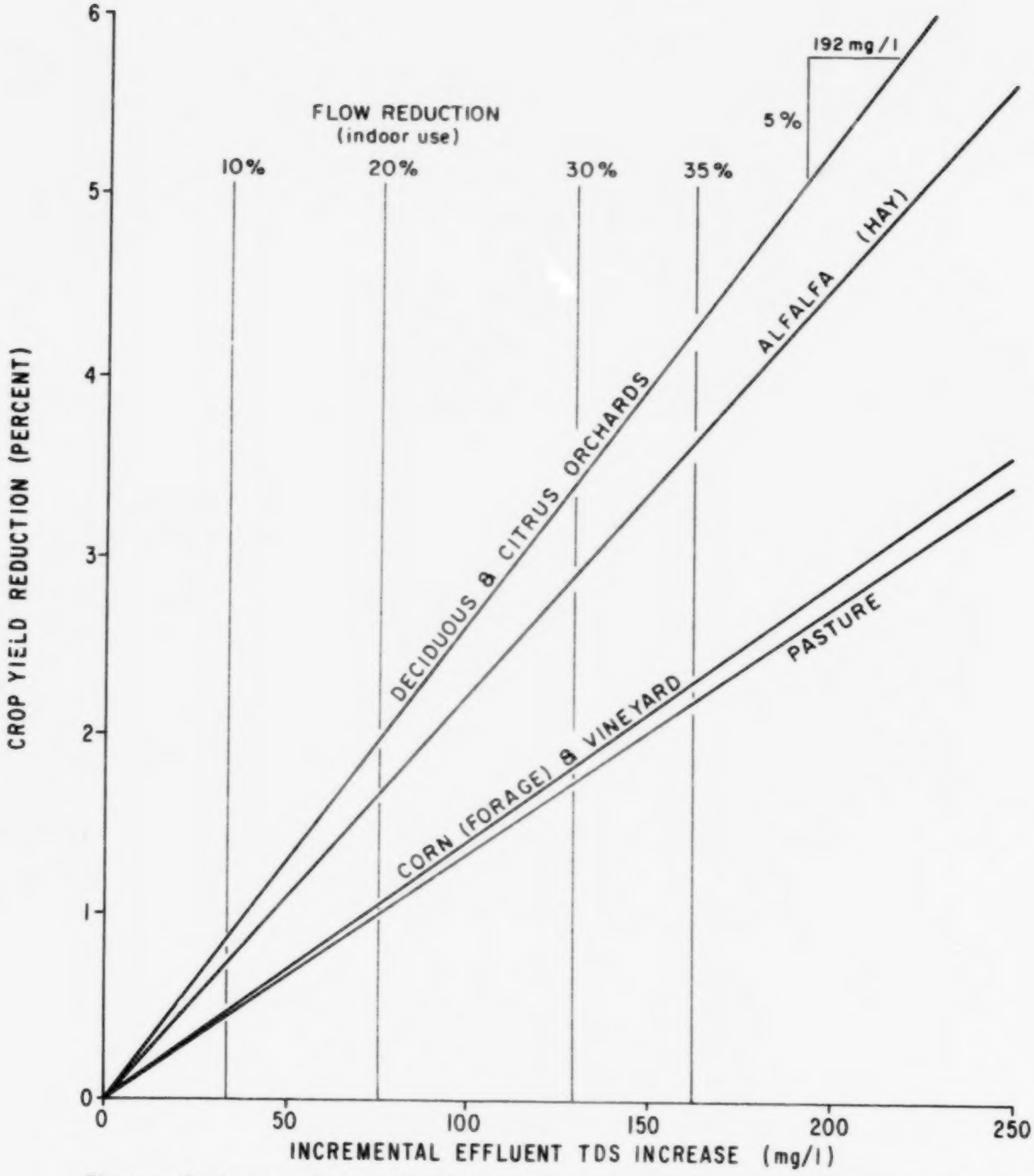


Figure 15. Crop yield reduction due to increased salt concentration.

TABLE 47. SUMMARY OF CROP LOSS DETERMINATION

Item		CROP								
		Hay	Pasture	Corn	Cotton	Barley	Citrus Orchard	Deciduous Orchard	Vineyard	Total
Amount of water	dam^3	34 255	44 760	7 185	27 020	16 860	5 490	745	2 675	
reclaimed[1]	(ac-ft)	(27,770)	(36,285)	(5,825)	(21,905)	(13,670)	(4,450)	(605)	(2,170)	
Crop land	hectare	2 615	3 280	740	2 255	3 790	1 070	75	310	
irrigated[2]	(acre)	(6,460)	(8,100)	(1,825)	(5,570)	(9,370)	(2,650)	(190)	(765)	
Unit applied water[3]	dam^3/hectare	13.10	13.66	9.72	11.98	4.45	5.12	9.75	8.63	
(weighted average)	(ac-ft/acre)	(4.30)	(4.48)	(3.19)	(3.93)	(1.46)	(1.68)	(3.20)	(2.83)	
Value	$/hectare	635	210	857	1 013	279	3 929	3 786	2 918	
crops[4]	($/acre)	(257)	(85)	(347)	(410)	(113)	(1,590)	(1,532)	(1,181)	
Value	$/$dam^3$	48.50	15.40	88.20	84.60	62.70	767.20	388.20	338.30	
crops[5]	($/ac-ft)	(59.80)	(19.00)	(108.80)	(104.30)	(77.40)	(946.40)	(478.80)	(417.30)	
Crop yield decrement, in percent										
at 10% indoor use reduction		0.7	0.5	0.4	0	0	0.9	0.9	0.4	
at 20% indoor use reduction		1.6	1.0	1.0	0	0	2.0	2.0	1.0	
at 30% indoor use reduction		2.9	1.8	1.8	0	0	3.4	3.4	1.8	
at 35% indoor use reduction		4.2	2.2	2.3	0	0	4.2	4.2	2.2	
Crop loss										
at 10% indoor use	$/$dam^3$	0.34	0.08	0.35	0	0	6.89	3.49	1.35	
reduction	($/ac-ft)	(0.42)	(0.10)	(0.43)			(8.50)	(4.31)	(1.67)	
at 20% indoor use	$/$dam^3$	0.78	0.15	0.88	0	0	15.35	7.77	3.38	
reduction	($/ac-ft)	(0.96)	(0.19)	(1.09)			(18.93)	(9.58)	(4.17)	
at 30% indoor use	$/$dam^3$	1.40	0.28	1.59	0	0	26.09	13.20	6.09	
reduction	($/ac-ft)	(1.73)	(0.34)	(1.96)			(32.18)	(16.28)	(7.51)	
at 35% indoor use	$/$dam^3$	2.03	0.34	2.03	0	0	32.23	16.30	7.44	
reduction	($/ac-ft)	(2.51)	(0.42)	(2.50)			(39.75)	(20.11)	(9.18)	
Crop loss (weighted average)										
at 10% indoor use	$/$dam^3$	0.08	0.02	0.02	0	0	0.28	0.02	0.02	0.44
reduction	($/ac-ft)	(0.10)	(0.03)	(0.03)			(0.34)	(0.03)	(0.03)	(0.54)
at 20% indoor use	$/$dam^3$	0.19	0.05	0.04	0	0	0.61	0.04	0.06	1.01
reduction	($/ac-ft)	(0.24)	(0.06)	(0.06)			(0.75)	(0.05)	(0.08)	(1.24)
at 30% indoor use	$/$dam^3$	0.35	0.09	0.08	0	0	1.03	0.07	0.11	1.73
reduction	($/ac-ft)	(0.43)	(0.11)	(0.10)			(1.27)	(0.09)	(0.14)	(2.14)
at 35% indoor use	$/$dam^3$	0.50	0.11	0.11	0	0	1.27	0.09	0.15	2.23
reduction	($/ac-ft)	(0.62)	(0.14)	(0.13)			(1.57)	(0.11)	(0.18)	(2.75)

NOTE: See next page for footnotes.

FOOTNOTES FOR TABLE 47

1/ From Department of Health Services Survey Report, "Wastewater Reclamation Facilities". 1978 (16).

2/ Crop types were first identified within specific regions in each county. The appropriate value of unit applied water for the crops was obtained from California Department of Water Resources Bulletin 113-3, "Vegetative Water Use in California, 1974" (19) and then used to estimate the number of hectares (acres) grown for each crop by the ratio:

$$\frac{\text{amount water reclaimed}}{\text{unit applied water}} = \frac{\text{dam}^3}{\text{dam}^3/\text{hectare}} \left(\frac{\text{ac-ft}}{\text{acre}}\right) = \text{hectare (acre)}.$$

3/ Amount of water reclaimed ÷ crop land irrigated.

4/ From California Department of Food and Agriculture Report, "California Principal Crop and Livestock Commodities 1978" (20).

5/ Value crops ($/hectare) ÷ unit applied water.

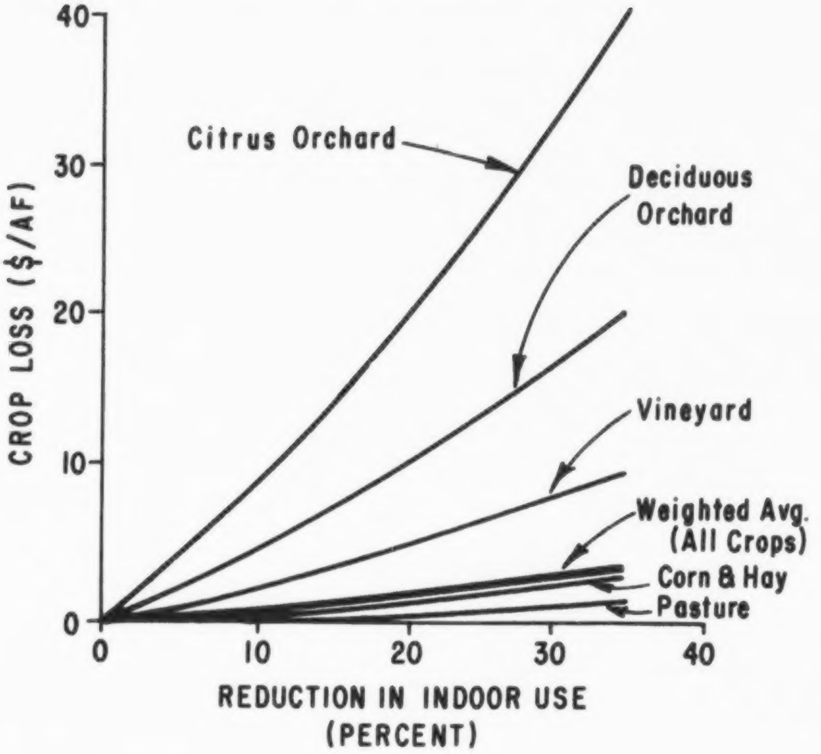
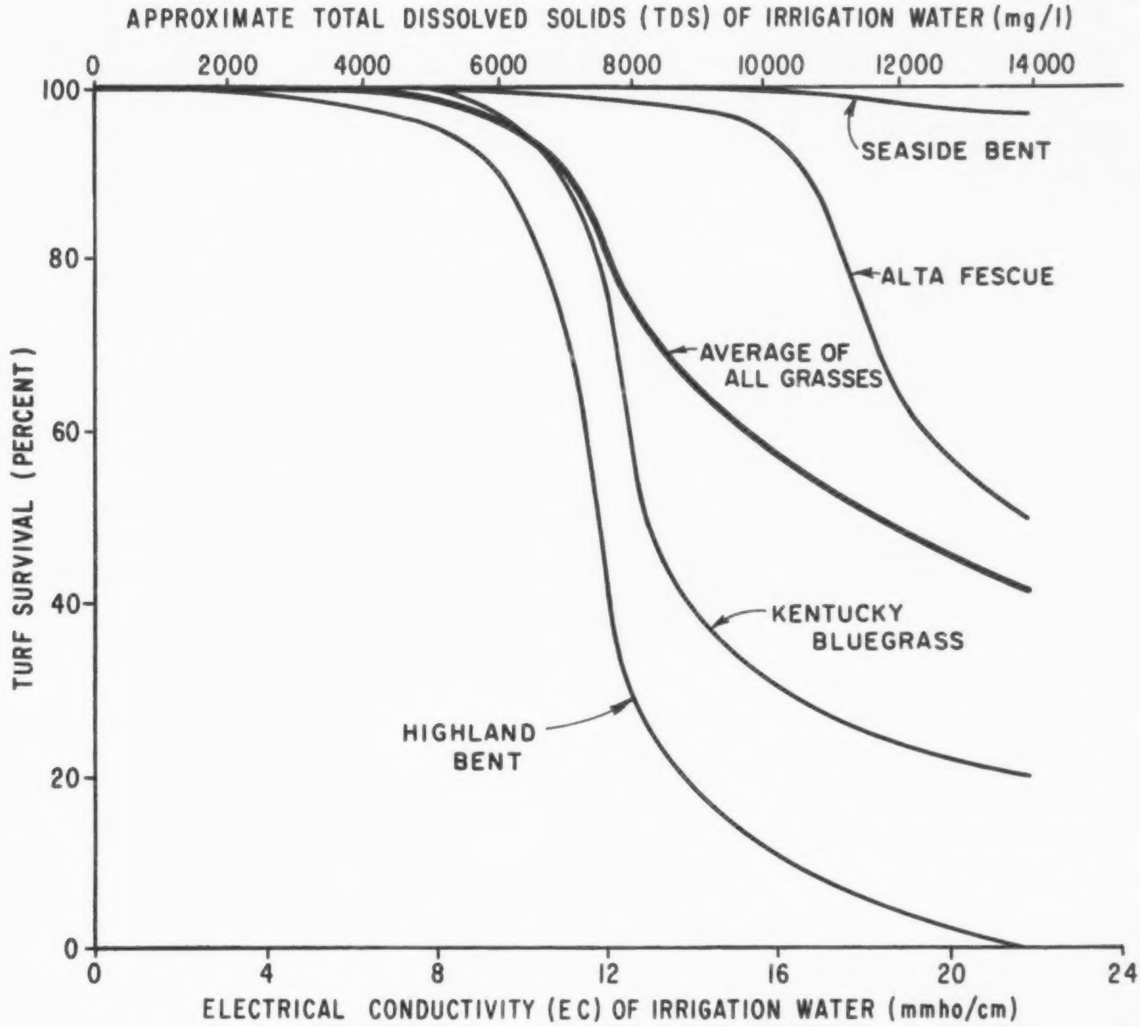


Figure 16. Impact of water conservation on reclamation of wastewater for crop irrigation.



Survival Rate based on values from "Salinity Tolerance of Five Turfgrass Varieties" by O. R. Lunt, V. B. Younger, and J. J. Oertli, Agronomy Journal (21).

Figure 17. Survival rate of turfgrass.

TABLE 48. UNIT COST OF WATER CONSERVATION MEASURES, CASE II

Water Conservation Measures	New Building Construction Only		Annual Cost $/Household
	Scenario 1 - Potential		
Toilet	No additional cost		0
Shower	No additional cost		0
Faucet	No additional cost		0
Pressure-Reducing Valve	Cost of material included		6.15[1/]
Hot Water Pipe Insulation	Cost of material included		4.05[1/]
Dishwasher/Clothes Washer	No additional cost		0
Education/Advertising	Cost Included		0.15[2/]
		TOTAL	10.35
	Scenario 2 - Moderate Water Conservation Effort		
Toilet	No additional cost		0
Shower	No additional cost		0
Faucet	No additional cost		0
Pressure-Reducing Valve	Cost of material included		0.60[1/]
Hot Water Pipe Insulation	Cost of material included		2.05[1/]
Dishwasher/Clothes Washer	No additional cost		0
Education/Advertising	Cost included		0.15[2/]
		TOTAL	2.80
	Scenario 3 - Minimal Water Conservation Effort		
Toilet, Shower, Faucet, Dishwasher/ Clothes Washer	No additional cost		0
Education	Cost included		0.10[2/]
		TOTAL	0.10

1/ All installation costs by plumbers were based on current (1979) plumber's wage scale. Annual unit cost reflects capital costs amortized at 7% interest, 5-year life.

2/ Education cost based on current student education program for water conservation by DWR. Advertising cost based on DWR water conservation pilot program in San Diego in 1977 updated to 1979 dollars.

TABLE 49. ANNUAL COST OF WATER CONSERVATION MEASURES, CASE II

Treatment Plant Size m^3/s (mgd)	Average[1] ADWF During 20-year Period m^3/s (mgd)	Number[2] of Households Served	Annual Cost of Water Conservation Measures[3] (in $1,000)		
			Scenario 1[4] 40% Indoor Water Use Reduction	Scenario 2[5] 35% Indoor Water Use Reduction	Scenario 3[6] 30% Indoor Water Use Reduction
0.04 (0.8)	0.01 (0.24)	1,165	10	5	0
0.11 (2.5)	0.03 (0.75)	3,635	40	10	0
0.55 (12.5)	0.16 (3.75)	18,180	190	50	0
1.10 (25)	0.33 (7.5)	36,365	375	100	5
2.19 (50)	0.66 (15)	72,730	750	205	5

1/ (Treatment plant size) x ($\frac{75\%}{125\%}$ flow relationship) ÷ 2.

2/ Average ADWF ÷ 3.29 x $10^{-6} m^3/s$/capita(75 gal/day/capita) x (2.75 occupants per household).

3/ (Number of households served) x (unit water conservation cost). Annual cost rounded to nearest $5,000.

4/ Scenario 1 - potential.

5/ Scenario 2 - moderate water conservation effort.

6/ Scenario 3 - minimal water conservation effort.

SECTION 7

WATER CONSERVATION NET BENEFITS

Summary

The benefits and costs of water conservation were examined in previous sections in order to view them in perspective to answer the question, "Is water conservation worthwhile?" The net worth of water conservation can be measured by determining its "net benefits", which is the difference between all its benefits and costs. Stated in another way, it is the excess of benefits over cost. A positive value indicates that a project or an effort is economically justified and a negative value that it is not. The point where the maximum excess benefits occur is the point of optimum development. An examination of the net benefits for Case I (new and existing building constructions) and Case II (new building construction only) showed that:

- There are considerable excess benefits over costs. For Case I, the optimum level of indoor water use reduction is nearly 30% and the benefits are about three times as great as the costs. For Case II, the optimum level is about 37% and the benefits far exceed costs.

- The optimum levels of water conservation would require an intensive water conservation effort.

- Water conservation in existing buildings for Case I is responsible for generating about 70% of the total net benefits.

Case I

The net benefits were examined for small, medium, and large wastewater systems and all showed the following:

- There are considerable excess benefits over costs.

- The optimum point of water conservation occurs at an overall community indoor water use reduction of almost 30% and would require a strong water conservation effort.

- The "impact on wastewater reclamation" has no noticeable effect on the net benefits.

The net benefits are shown in Table 50, and an example of a net benefit curve is shown in Figure 18.

Case II

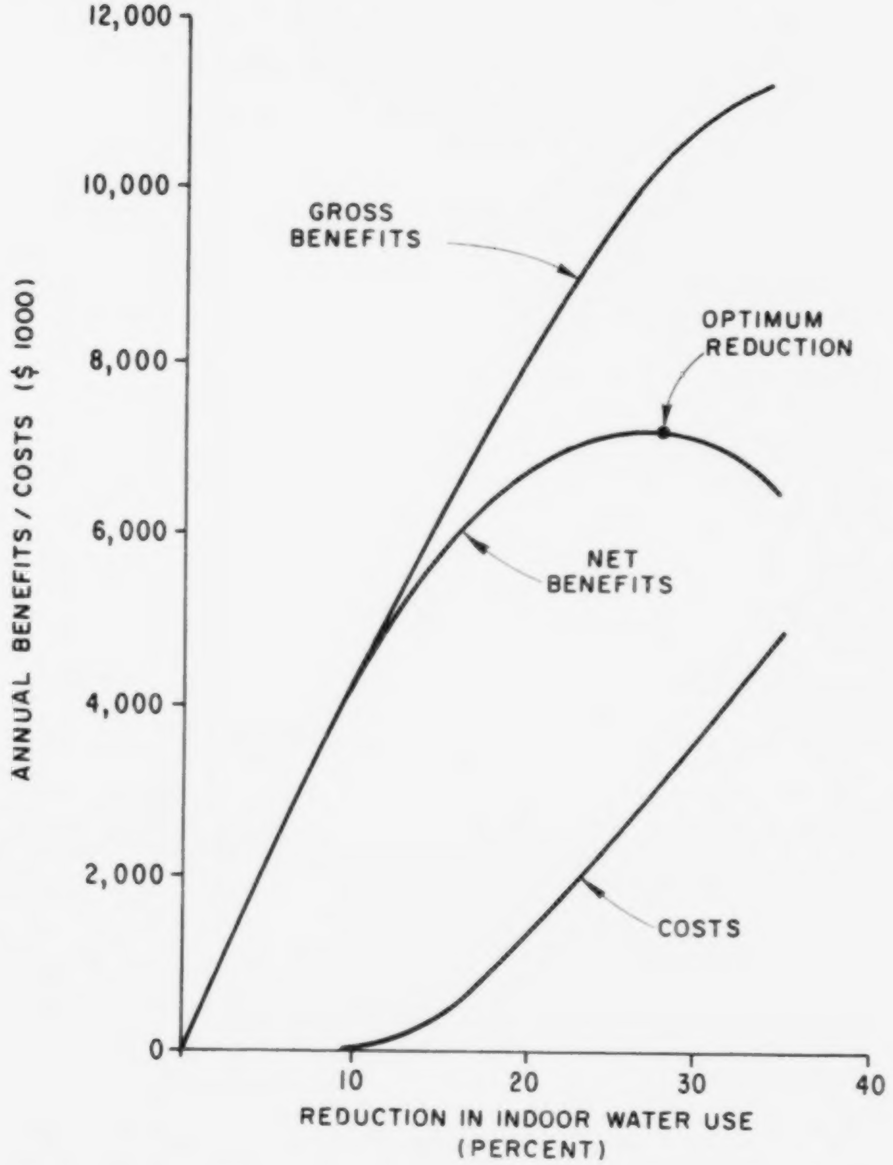
As in Case I, the net benefits were examined for small, medium, and large wastewater systems and showed the following:

- There are considerable excess benefits over costs.
- The optimum point of water conservation effort occurs at an indoor water use reduction of about 37%
- The "impact on wastewater reclamation" has no noticeable effect on the net benefits.
- The net benefits are considerably less than those for Case I. An example of a net benefit curve is shown in Figure 19. It has been plotted at the same scale as for Case I for easy comparison. Another comparison in Figure 20 shows the dramatic beneficial effect of water conservation in existing buildings.

The net benefits for all of the wastewater system sizes examined are shown in Table 51.

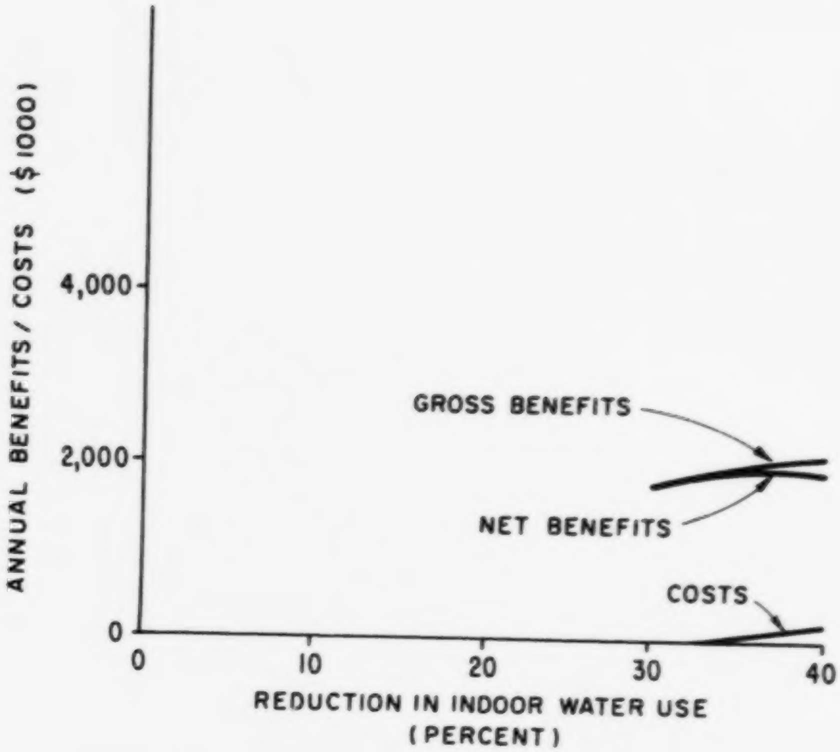
TABLE 50. NET BENEFITS OF WATER CONSERVATION, CASE I

Treatment Plant Size m^3/s (mgd)	Percent Reduction in Indoor Water Use	Annual Gross Benefits (in $1,000)	Annual Costs (in $1,000)	Annual Net Benefits (in $1,000)
0.04 (0.8)	10	260	0	260
	20	510	85	425
	30	680	230	450
	35	705	305	400
0.11 (2.5)	10	800	5	795
	20	1,570	270	1,300
	30	2,005	720	1,285
	35	2,195	960	1,235
0.55 (12.5)	10	4,300	30	4,270
	20	8,070	1,345	6,725
	30	10,690	3,605	7,085
	35	11,260	4,790	6,470
1.10 (25)	10	8,670	65	8,605
	20	16,310	2,685	13,625
	30	20,565	7,210	13,355
	35	22,530	9,580	12,950
2.19 (50)	10	16,680	125	16,555
	20	32,040	5,375	26,665
	30	42,555	14,415	28,140
	35	44,485	19,155	25,330



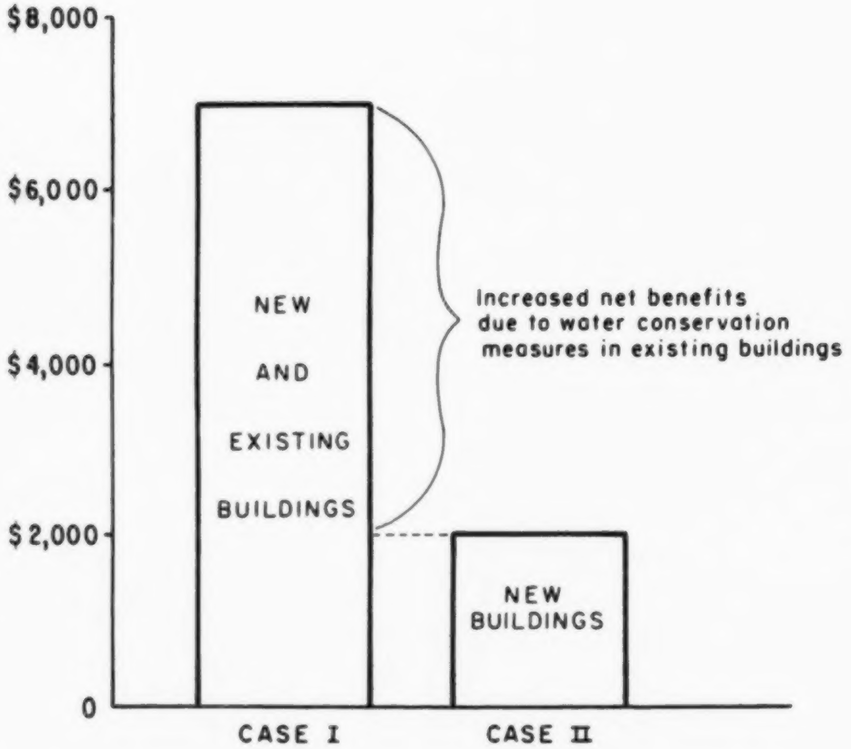
NOTE: Optimum level of indoor water use reduction is nearly 30% and requires an intense water conservation effort. This illustration pertains to 0.55 m^3/s (12.5mgd) treatment plant size.

Figure 18. Annual water conservation net benefits, Case I.



EXAMPLE: 0.55 m^3/s (12.5 mgd) Treatment Plant Size.

Figure 19. Annual water conservation net benefits, Case II.



EXAMPLE: 0.55 m^3/s (12.5 mgd) Treatment Plant Size.

Figure 20. Annual net benefits of water conservation at optimum level of indoor use reduction.

TABLE 51. NET BENEFITS OF WATER CONSERVATION, CASE II

Treatment Plant Size m^3/s (mgd)	Percent Reduction in Indoor Water Use	Annual Gross Benefits (in $1,000)	Annual Costs (in $1,000)	Annual Net Benefits (in $1,000)
0.04 (0.8)	30	90	0	90
	35	105	5	100
	40	115	10	105
0.11 (2.5)	30	290	0	290
	35	335	10	325
	40	355	40	315
0.55 (12.5)	30	1,790	0	1,790
	35	2,015	50	1,965
	40	2,125	190	1,935
1.10 (25)	30	3,725	5	3,720
	35	4,270	100	4,170
	40	4,478	375	4,103
2.19 (50)	30	6,775	5	6,770
	35	8,000	205	7,795
	40	8,405	750	7,655

SECTION 8

PENALTY COSTS

Background

In this section, the "penalty costs" of water conservation will be examined. Penalty costs are costs borne by domestic water users as a result of increased TDS and hardness concentrations and are associated with:

- Home water softeners
- Soap and detergent
- Bottled water
- Shorter service life of water heaters.

These costs are often borne in areas where the water supply usually has a high salt concentration. When an incremental increase in effluent hardness and TDS concentrations occurs as a result of wastewater flow reduction, some consumer, somewhere, at some time could bear penalty costs. No attempt will be made to measure the actual penalty cost to a particular consumer because it depends on many variables such as the place of discharge of the sewage effluent, the amount of effluent that mixes with a usable water supply, the extent to which the effluent alters the quality of that water supply, and the quality of the water supply that is being used by the consumer.

For example, if the effluent is discharged to the ocean, it is being returned to a "nonusable" water supply and therefore no penalty costs would be incurred. The worst possible case would be a direct domestic use of the effluent, although this is highly unlikely in the forseeable future. Nevertheless, this condition sets an upper limit of penalty costs to get some perspective in relation to the net benefits of water conservation and therefore will be examined in this section.

In the Section 6 discussion on impact on wastewater reuse for Case I, it was found that there were an incremental increase in the TDS concentration in the wastewater when reductions occurred in indoor water use. In a similar way, there is an incremental increase in the hardness concentration. Because adequate data was not available from treatment plants surveyed or other plants on this factor, the incremental increase in TDS and hardness concentrations were estimated as follows and are shown on Figure 21:

Percent Reduction in Indoor Water Use	TDS Pick-up Due to Domestic Use with Water Conservation (in mg/l)	Incremental TDS Increase (in mg/l)	Hardness Pick-up Due to Domestic Use with Water Conservation (in mg/l)	Incremental Hardness Increase (in mg/l)
10	$\frac{300}{0.9} = 333$	333-300 = 33	$\frac{60}{0.9} = 67$	67-60 = 7
20	375	75	75	15
30	429	129	86	26
35	462	162	92	32

The incremental increases are based on mineral pick-up in water due to domestic use of 300 mg/l TDS and 60 mg/l hardness (18).

Unit Penalty Costs

Information from a study[1] indicates the following unit penalty costs:

• Cost of soap and detergent • Cost of home water softeners • Cost of bottled water	$56.10/dam^3 ($69.20/ac-ft) per 100 mg/l hardness increase
• Capital cost related to shorter service life of water heaters	$4.08/dam^3 ($5.03/ac-ft) per 100 mg/l TDS increase

The study considered TDS and hardness as the major water quality factors that apply to areas of water supply with high TDS and hardness concentrations such as in Southern California. The above values do not account for all of the consumer costs associated with TDS and hardness such as costs associated with washing machines, pipes, and plumbing fixtures which would tend to increase the consumer costs. On the other hand, the scaling problems in plumbing fixtures caused by hard water would be lessened with greater use of home water softeners and would tend to offset those costs not taken into account. In summary, the penalty costs shown are considered to include the major components and are adequate to give an indication of the magnitude of values.

Annual Penalty Costs

The unit penalty costs were applied to the amount of water saved to find the annual penalty costs (see Table 52).

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[1] "Consumer Costs of Water Quality in Domestic Water Use Lompoc Area", California Department of Water Resources. June 1978 (22).

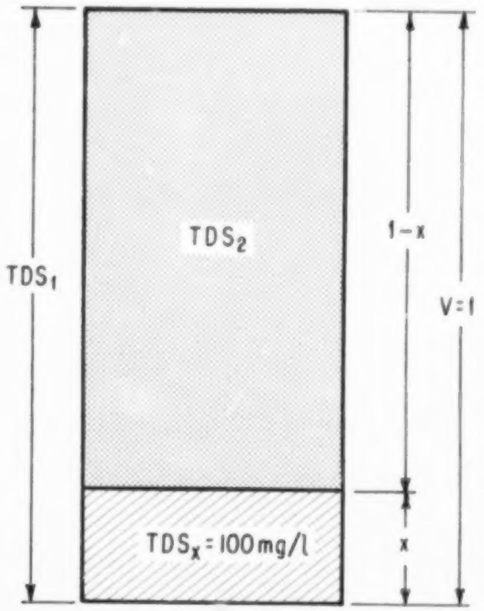
Effect on Net Benefits

To illustrate the effect of penalty costs on the net benefits, take the Case I net benefits curve for a 0.55 m^3/s (12.5 mgd) treatment plant size and apply the upper limit of the penalty costs. We find that this does not significantly change the net benefits curve (see Figure 22). The net benefits curve for the other treatment plant sizes is similarly affected.

Alternative to Penalty Costs

An alternative to penalty costs through mitigation of the incremental increase in the effluent salt concentration will be examined here. The cost of desalting a portion of the effluent and then blending the desalted water with the effluent to attain the salt concentration prior to reduction in wastewater flow will be approximated and compared with the penalty costs.

In order to quantify the cost of desalting, it is necessary to know the TDS concentration of the effluent. In an area where penalty costs are commonly incurred as in Southern California, an effluent TDS of 1050 mg/l (23) is chosen as typical for that area. As discussed earlier in this section, a mineral pick up of 300 mg/l due to domestic use will also be used. The amount of effluent required to be desalted and the unit cost of desalting is shown in Table 53. The details of determining the amount requiring desalting are shown below:



LET:

x = volume of effluent to be desalted

$V=1$ = total volume of effluent

$1-x$ = volume of effluent before blending (This neglects a small portion of the effluent that would be lost as a concentrated process brine).

TDS_1 = TDS of effluent before flow reduction (1 050 mg/l)

TDS_2 = TDS of effluent after flow reduction

$TDS_2 - TDS_1$ = TDS change due to flow reduction

TDS_x = TDS of desalted water (100 mg/l)[1]

---

[1] From experiences of Orange County Water District desalting plant and pilot desalting plant in Marin County at about 90% salt removal.

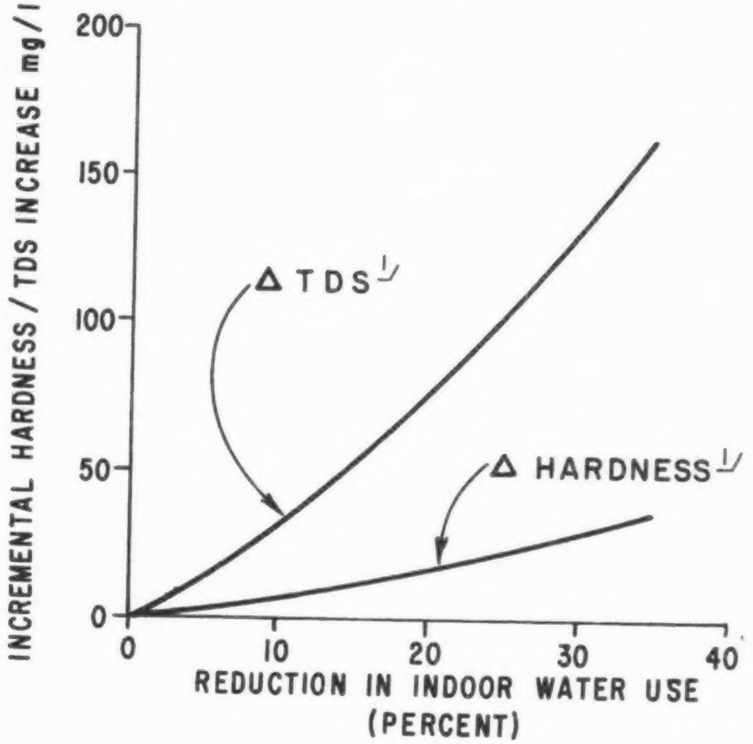
Effluent quality before reduction = Effluent quality after blending

$$TDS_1 \ (1) \ = \ TDS_2 \ (1-x) \ + \ TDS_x \ (x)$$

$$TDS_2 \ (x) \ - \ TDS_x \ (x) \ = \ TDS_2 \ - \ TDS_1$$

$$x\% = \frac{TDS_2 - TDS_1}{TDS_2 - TDS_x} = \frac{[\text{TDS Change due to flow reduction}]}{[\text{TDS of effluent after flow reduction - 100}]} \times 100$$

The unit cost of desalting without the cost of brine removal is about the same as the upper limit of the penalty costs, whereas those with brine removal costs are considerably greater (see Figure 23). Brines are a concentrated by-product of the desalting process which must be removed to a suitable place. For desalting plants located near a saline body of water, the brine removal costs are either minimal or non-existent. It seems that with the current state-of-the-art of desalting secondary treated wastewater, desalting is not a justifiable measure as an alternative to incurring penalty costs.

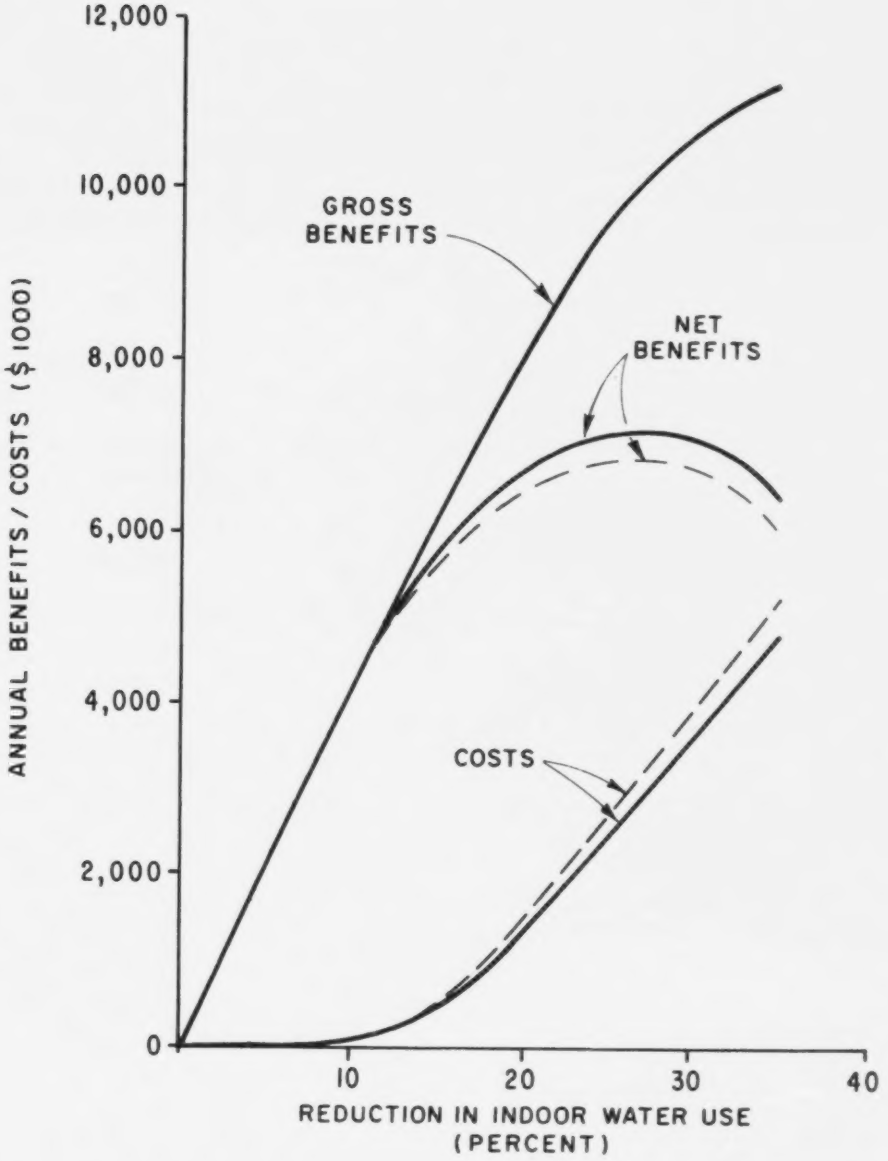


[1] Based on mineral pickup in water due to domestic use of 300 mg/l TDS and 60 mg/l hardness. SOURCE: State Water Pollution Control Board Publication No. 9, 1954 (18).

Figure 21. Incremental increase in TDS and hardness concentrations.

TABLE 52. ANNUAL PENALTY COSTS, CASE I

Treatment Plant Size	Water Savings dam^3 (ac-ft)					Annual Penalty Costs (in $1,000)			
m^3/s (mgd)	Percent Indoor Use Reduction	10	20	30	35	10	20	30	35
0.04 (0.8)		224 (182)	533 (432)	842 (683)	998 (809)	0	10	20	30
0.11 (2.5)		703 (570)	1 662 (1,347)	2 629 (2,131)	3 115 (2,525)	5	25	65	95
0.55 (12.5)		3 515 (2,850)	8 299 (6,728)	13 123 (10,639)	15 548 (12,605)	25	120	325	475
1.10 (25)		7 038 (5,706)	16 620 (13,474)	26 285 (21,309)	31 143 (25,248)	45	240	650	955
2.19 (50)		14 077 (11,412)	33 239 (26,947)	52 571 (42,619)	62 287 (50,496)	90	475	1,305	1,910



NOTE: Dashed lines represent costs and net benefits including penalty costs. Illustration pertains to 0.55 m^3/s (12.5 mgd) treatment plant size for Case I. Impact for Case II is similar.

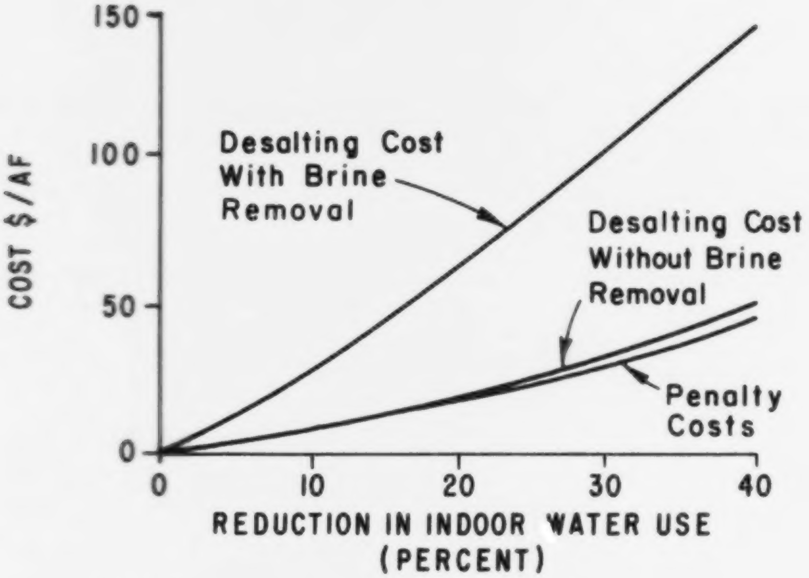
Figure 22. Effect of penalty costs on net benefits.

TABLE 53. AMOUNT AND COST OF DESALTING

Percent Reduction in Indoor Water Use	Effluent TDS Before Flow Reduction mg/l	TDS Change Due to Flow Reduction mg/l	Effluent TDS After Flow Reduction mg/l Col.2 + Col.3	Amount of Effluent to be Desalted & Blended (in %) Col.3 / Col.4-100	Cost of Desalting \$/dam^3 (\$/ac-ft) Col.5 x \$673/dam^3 (830/ac-ft)[1]	Cost of Desalting \$/dam^3 (\$/ac-ft) Col.5 x \$211/dam^3 (260/ac-ft)[2]
10	1050	33	1083	3.4	22.90 (28.20)	7.10 (8.80)
20	1050	75	1125	7.3	49.10 (60.60)	15.40 (19.00)
30	1050	129	1179	12.0	80.70 (99.60)	25.30 (31.20)
35	1050	162	1212	14.1	94.90 (117.00)	29.80 (36.70)

1/ Based on City of Ramona reverse osmosis plant.
Capacity = 0.01 m^3/s (0.25 mgd).
Desalting cost = \$673/dam^3 (\$830/ac-ft).
Brine removal constitutes about 63% of desalting cost

2/ Based on Orange County Water District reverse osmosis plant.
Capacity = 0.22 m^3/s (5 mgd).
No brine removal.
Desalting cost = \$164/dam^3 (\$202/ac-ft) at July 1975 prices.
Cost adjusted to 1979 prices = \$211/dam^3 (\$260/ac-ft).



NOTE: The cost of desalting shown reflects the costs in terms of the total volume of blended wastewater.

Figure 23. Comparative cost of alternative (by desalting) to "Penalty Costs".

SECTION 9

SAVINGS IN FUTURE EXPENDITURES FOR SECONDARY TREATMENT PLANTS

The estimated capital expenditures (24) for secondary treatment plants in California to the year 2000 is $764,920,000 for enlargement of existing plants and $566,390,000 for construction of new plants that would be operated independent of existing facilities. Previously two cases were analyzed for the same conditions as follows:

> Case I - New wastewater facilities are additions to or expansions of existing facilities to take care of new population growth.
>
> Case II - New wastewater facilities serve new population growth and operate independent of existing facilities.

Therefore, the analyses for these cases are applicable and were used to approximate the order of magnitude ot capital savings in future expenditures when water conservation is undertaken. The estimated savings are shown in Table 54 and are additive.

At the optimum level of water conservation effort, the approximate savings from Table 54 are:

Case	Approximate[1/] Optimum Level of Water Conservation Effort (in %)		Approximate Future Capital Savings (in $1,000)
I	30		168,000
II	37		44,000
		Total	212,000
		Rounded	210,000

There would also be expected savings in capital expenditures for two other categories -- upgrading to secondary treatment level and upgrading and enlargement of existing plants. However, there was not sufficient available information to examine this aspect.

1/ From net benefits curves.

TABLE 54. ESTIMATED SAVINGS IN CAPITAL EXPENDITURE FOR SECONDARY TREATMENT PLANTS PROPOSED FOR NEW CONSTRUCTION AND ENLARGEMENT IN CALIFORNIA

Case I - Enlargement of Existing Plants

Estimated Expenditures to Year 2000 (in $1,000)	Percent Reduction in Indoor Water Use	Capital Cost Savings (in percent)	Capital Cost Savings (in $1,000)
764,920	10	11.8	90,260
	20	21.5	164,460
	30	22.0	168,280
	35	22.0	168,280

Case II - New Plant Construction

Estimated Expenditures to Year 2000 (in $1,000)	Percent Reduction in Indoor Water Use	Capital Cost Savings (in percent)	Capital Cost Savings (in $1,000)
566,390	30	6	33,980
	35	7	39,650
	40	8	50,980

SECTION 10

IMPLEMENTATION OF WATER CONSERVATION MEASURES

In summary, the results of the study concerning indoor water conservation showed the following major points:

- The benefits of water conservation substantially exceed its costs. Benefits are generated by savings in energy and water uses and expenditures on wastewater systems.
- Water conservation measures in existing buildings are highly important since substantial greater benefits are generated by measures in existing buildings than in new buildings.
- The operational problems encountered in wastewater systems during periods of flow reductions were generally not so severe that they greatly upset systems operations. Remedial measures were taken to resolve the problems so that proper operation could be continued.
- Changes in wastewater quality during periods of flow reduction did not generally cause treatment plants to more frequently exceed their BOD and SS effluent limitations.
- Water conservation is not counterproductive to wastewater reclamation.
- An intensive water conservation effort is necessary to attain the optimum level of water use reductions where the greatest benefits over costs occur.

In recent years, water conservation has gained much attention and is publicly acclaimed by many as an essential element of effectively managing our water resources. As a result, many have undertaken water conservation measures, but often without the benefit of a full knowledge of its positive and negative effects. This study quantitatively confirms the desirability of water conservation, and supports the need to vigorously implement water conservation measures. The importance of water conservation in reducing the expenditures in wastewater systems is also recognized in the Federal Water Pollution Control Act (PL 92-500) as amended. It requires an analysis of cost effective water conservation measures for each facility planning area as a condition for federal grant funding of wastewater facilities.

However, the positive results of this study, the public acclaim, the federal regulations for cost effective analysis, or existing policies which all promote water conservation do not necessarily cause a community to undertake concerted water consevation efforts in a non-crisis water supply situation. This is indicated by the sudden increase in the amount of wastewater flow in California during the year immediately following the drought. This increase[1] averaged 34% although the flow quantity did not reach the pre-drought flows. However, the tendency for the community to revert to old habits does point out a need for an understanding -- an understanding of the "incentives" of water conservation from different points of view in the community. Urban water use involves various elements of interests concerning water supply development and treatment, delivery, consumer use, and wastewater treatment and disposal. Although water conservation may result in a net economic gain to a community when viewed as a whole system as was done in this report, the financial impact differs with each element in the system.

The solution approach is to investigate the financial/social gains or losses of water conservation from at least three points of view -- the water supplier, the consumer, and the waste discharger and include the following considerations:

Water Supplier

- Reduced water delivery requirements
- Cost savings due to reduced distribution of water
- Cost savings in treatment of water delivered
- Cost savings in future capital expenditures for water supply facilities
- Deferred capital expenditure for future water supply facilities
- Reduction in purchased water
- Loss of revenues requiring adjustment of price and/or reduction in operation cost

Consumer

- Energy cost savings
- Water cost savings

1/ In the year immediately following the drought, wastewater flows increased 34% as compared to the previous year, but were still 15% less than the predrought flows.

Waste Discharger

- Cost savings in operation and maintenance of sewer systems
- Cost savings in future capital expenditures for wastewater facilities
- Deferred capital expenditures for future wastewater facilities
- Satisfaction of grant requirements for financing wastewater facilities

Items Common to All Elements

- Positive public image and ethics for promoting water conservation
- Cost of water conservation measures

Various communities in California and elsewhere experienced the effects of water conservation during the drought. Their experiences in the form of available data could be used in analyzing the financial/social gains and losses.

When community interests understand the benefits to themselves as well as to the total community a willingness to take action is generated and leads to the development and implementation of a workable plan.

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APPENDIX A

ASSEMBLY BILL NO. 1395. AN ACT TO ADD SECTION 17921.3 TO THE HEALTH AND SAFETY CODE, RELATING TO WATER CLOSETS

CHAPTER 91

An act to add Section 17921.3 to the Health and Safety Code, relating to water closets.

[Approved by Governor April 2, 1976. Filed with
Secretary of State April 2, 1976.]

LEGISLATIVE COUNSEL'S DIGEST

AB 1395, Keene. Water closets.

There is no statutory existing law regarding the use of water closets in construction of buildings used for human habitation.

This bill would prohibit the construction of new hotels, motels, apartment houses, and dwellings after January 1, 1978, which are equipped with tank-type water closets which use more than an average of 3½ gallons of water per flush and are not approved by the State Department of Housing and Community Development according to specified standards. Such requirement would only be applicable to new additions to, or renovations of, existing structures if compliance would not require substantial modification of the existing plumbing system. The bill would require the department to permit the installation of tank-type water closets equipped with devices reducing average water consumption to no more than 3½ gallons per flush. The department would be required to periodically publish a list of acceptable water closets and devices in its regulations.

This bill would permit a manufacturer to sell water closets which do not meet such requirements in a quantity sufficient to meet the need for water closet installation or replacement in structures other than new hotels, motels, apartment houses, and dwellings, or when authorized by the local enforcement agency.

This bill would permit the local enforcement agency to allow the use of standard flush toilets under specified circumstances. The requirements of the bill would be inapplicable in areas subject to prescribed waste discharge requirements.

The bill would also permit the Commission of Housing and Community Development to suspend the requirements imposed by this bill by adoption of a regulation based upon a determination that there is an inadequate supply of such water closets to meet the need in new construction or that such water closets are not available at a reasonable price.

Violations of the provisions of this bill would be misdemeanors under existing statutory law.

The bill would provide that there would be no reimbursement of, or appropriation to, local governmental agencies for state-mandated local program costs imposed by the bill because of a specified reason.

The people of the State of California do enact as follows:

SECTION 1. Section 17921.3 is added to the Health and Safety Code, to read:

17921.3. After January 1, 1978, no new hotel, motel, apartment house, or dwelling shall be constructed which employs a tank-type water closet that uses more than an average of 3½ gallons of water per flush and which is not approved by the department as meeting adequate standards of safety and sanitation. Such requirement shall only be applicable to new additions to, or renovations of, existing hotels, motels, apartment houses, and dwellings if, compliance with the requirements of this section will not require substantial modification of the existing plumbing system. In satisfaction of the requirements of this section, the department shall permit the installation of tank-type water closets equipped with devices which are found by the department to meet applicable performance standards, that reduce average water consumption to no more than 3½ gallons per flush, in water closets having a tank capacity in excess of 3½ gallons. The department shall periodically publish a list of acceptable water closets and devices to reduce water consumption.

A manufacturer may sell water closets in this state which do not meet the foregoing requirements in a quantity sufficient to serve the need for water closet installation or replacement in structures other than new hotels, motels, apartment houses, or dwellings, or when authorized by the local enforcement agency.

Any local enforcement agency may allow the use of standard flush toilets, when, in the opinion of the local agency, the configuration of the building drainage system requires a greater quantity of water to adequately flush the system.

This section shall not apply in any local jurisdiction, area, or region of the state subject to waste discharge requirements imposed pursuant to Article 4 (commencing with Section 13260) of Chapter 4 of Division 7 of the Water Code when the local enforcement agency determines that the waste water discharges would exceed such waste discharge requirements if this section was made applicable.

The requirements prescribed by this section may be suspended for a specified period of time by a regulation adopted by the commission when the commission finds that there is an inadequate supply, including a choice of styles or colors for the consumer, of water closets specified in this section to meet the needs of new construction, or such water closets are not available at reasonable prices as compared to water closets not complying with the requirements of this section.

SEC. 2. Notwithstanding Section 2231 of the Revenue and Taxation Code, there shall be no reimbursement pursuant to that section nor shall there be any appropriation made by this act because the duties, obligations or responsibilities imposed on local government by this act are minor in nature and will not cause any financial burden to local government.

APPENDIX B[1]

CALIFORNIA ADMINISTRATIVE CODE

TITLE 20, CHAPTER 2

SUBCHAPTER 4: ENERGY CONSERVATION
ARTICLE 4: APPLIANCE EFFICIENCY STANDARDS

1601. Scope. Unless otherwise indicated, the provisions of this article shall apply to the following types of new appliances sold in California:

* * * * *

(f) Plumbing fittings, including showerheads, lavatory faucets and sink faucets.

1602. Definitions. For the purpose of this article the following definitions shall apply:

(a) General

(1) "Accepted laboratory" means any testing laboratory approved by the Commission for testing of a particular type of appliance.

(2) "Date of sale" means the day when the appliance is physically delivered to the buyer.

(3) "Failure modes and effects analysis" means an analysis of a particular design which describes the most probable ways systems and components can fail, the consequences of such failures, and design steps taken to minimize or reduce the possibility of their occurrence.

(4) "Intermittent type ignition device" means any ignition system on a gas appliance which is not a continuously burning gas pilot light.

1/ This appendix contains excerpts from the California Administrative Code and pertains only to plumbing fixtures. Omissions applying to other appliances are denoted by *****.

(5) "Manufacturer" means any person engaged in the production or assembly of an appliance. Manufacturer also includes any person whose brand or trademark appears on such appliance, if the brand or trademark of the person actually producing or assembling the appliance does not appear on the appliance.

(6) "Marking plate" means a plate, located so as to be easily read when the appliance is in a normally installed position.

* * * * *

(f) Plumbing Fittings

(1) "Lavoratory faucet" means a plumbing fitting designed for discharge into a lavoratory.

(2) "Plumbing fittings" means a device designed to control and/or guide the flow of water into or convey water from a fixture.

(3) "Showerhead" means a device through which water is discharged for a shower bath.

(4) "Sink faucet" means a plumbing fitting designed for discharge into a sink. "Sink faucet" does not include utility faucets designed for use with service sinks.

1603. Test Methods.

* * * * *

(f) Plumbing Fittings. The manufacturer shall cause the testing of samples of each model of showerhead, lavatory faucet and sink faucet to be sold in California.

A sample of sufficient size of each model shall be tested to insure that the flow rate certified under the provisions of Section 1605 shall be no less than the mean of the sample or the upper 97-1/2 percent confidence limit of the true mean divided by 1.05.

The maximum flow rate shall be measured using the test procedure approved by the American National Standards Institute on October 2, 1975, and known as ANSI A112.18.1-1975 with Section 5.14 modified to read as follows:

"5.14 Discharge

The inlet(s) of the fitting, with standard accessories, shall be connected to smooth pipe or tubing of the same nominal diameter as the fitting outlet, which is at least 20 inside diameters long.

Upstream pressure tap(s) shall be located 1/2 to 2-1/2 inside diameters upstream from the fitting inlet. Pressure tap size and configuration shall conform with ASME Performance Test Code Supplement, Instruments and Apparatus, PTC 19.2-1964 Part 2--Pressure Measurement, paragraph 2.05. Pressure Transducers on gauges shall be calibrated as per PTC 19.2-1964, Chapter 4.

The fitting shall be thoroughly flushed before measuring the flow rate.

Water at a temperature of 140°F plus or minus 5°F shall be discharged from the fitting for 10 minutes. The test for water discharge rate shall then be performed with water whose temperature is 100°F plus or minus 5°F. The fitting shall then be examined to ensure that the parts have not been damaged by the hot water. The test pressure at the inlet shall cover a range between 20 and 80 psig when flowing. All fittings shall be tested at maximum flow setting. The rates of flow used for certification under the provisions of Section 1605 shall be the maximum rate of flow at any supply pressure between 20 and 45 psig and the maximum rate of flow at any supply pressure between 45 and 80 psig.

If a fluid meter is used to measure flow rate, the installation shall be in accordance with ASME Supplement 19.5 on Instruments and Apparatus, Application, Part II of Fluid Meters, 1972."

1604. Efficiency Standards.

* * * * *

(f) Plumbing Fittings

The maximum flow rate of all new showerheads, lavatory faucets, and sink faucets manufactured on or after the date specified in Table F shall be certified not to exceed the values shown.

TABLE F

Effective Date	Appliance	Test Pressure	Maximum Flow Rate
December 22, 1978	Plumbing Fittings		
	Showerheads	20-45 psig	2.75 gpm
		45-80 psig	3.00 gpm
	Lavatory faucets	20-80 psig	2.75 gpm
	Sink faucets	20-80 psig	2.75 gpm

1605. Certification.

(a) No new gas appliance of the type described in Table G may be sold or offered for sale in California on or after the effective date shown, unless it has been certified by the Commission to comply with the requirements of Subsections 1603(d)(4), 1603(d)(5), 1603(d)(6), 1603(e)(3), 1603(e)(4), 1603(g) and 1603(h) of this Article.

TABLE G

Effective Date	Appliance
July 8, 1978	Fan type central furnaces Household cooking appliances
February 10, 1979	Clothes dryers
December 22, 1979	Fan type wall furnaces
24 months after certification of the first swimming pool heater	Swimming pool heaters

(b) No new appliance described in Subsections 1601(a) through (f) of these regulations (except swimming pool heaters) may be sold or offered for sale in California on or after the effective dates listed in Section 1604 of these regulations unless the manufacturer has provided sufficient information about the model number or other indentification by which the date of manufacture can be readily ascertained.

(c) No new appliance described in Subsections 1601(a) through (f) of these regulations, (except swimming pool heaters), which was manufactured on or after the effective dates listed in Section 1604 of these regulations, shall be sold or offered for sale in California, which is not certified by its manufacturer to be in compliance with the provisions of this Article. One year after such effective date, no new appliance described in Section 1601 of these regulations, regardless of the date of manufacture, may be sold or offered for sale in California, which is not certified by its manufacturer to be in compliance with the provisions of this Article. Certification is not required, however, for models of appliances whose production ceased before November 3, 1977, if it can be readily ascertained from the label or nameplate that its efficiency meets the applicable value specified in Section 1604 of this Article. The requirements referred to in Subsection 1665(a) are excluded from the requirements of this subsection.

* * * * *

(e) The manufacturer shall submit a certification statement to the executive director for each model, containing the following information, except as provided in Subsection (f):

(1) Name and address of manufacturer.

(2) Type of appliance.

(3) Brand name.

(4) Model number, as it appears on the appliance name plate.

(5) Name and address of laboratory where test for efficiency was performed.

(6) Date of test for efficiency.

(7) Results of the test for efficiency as follows:

* * * * *

(F) Plumbing Fittings

1. Maximum flow rate (showerheads at 20-45 psig).
2. Maximum flow rate (showerheads at 45-80 psig).
3. Maximum flow rate (lavatory faucets and sink faucets at 20-80 psig).

(8) Sufficient information about the model number or other identification by which the date of manufacture can be readily ascertained.

(9) A declaration that the appliance model complies with Article 4, Subchapter 4, of Title 20, of the California Administrative Code. the executive director may at his discretion, prescribe a standard form for the certification statement.

1606. Identification of Complying Appliances. (a) Sufficient information shall be shown on the outside of the shipping carton for any appliance described in Subsections 1601(a) through 1601(f) (and unit carton in the case of plumbing fittings) to permit the determination of whether the appliance complies with the requirements of this article. The manufacturer may display the following information on the outside of the carton to show compliance:

(1) The Commission's compliance seal;

(2) The appropriate measure of energy consumption or efficiency;

(3) The model number as it has been certified and information to determine date of manufacture; or

(4) Other information sufficient to show compliance.

The executive director or his designee may require additional information if necessary to permit determination of compliance.

(b) The name or brand of the manufacturer shall appear on each appliance.

* * * * *

1607. Enforcement. (a) Notwithstanding the provisions of Section 1605 of these regulations, the executive director shall have authority to challenge the efficiency test results provided by the manufacturer and cause the appliance model to be retested at any voltage for which it is labeled.

(b) The executive director shall cause periodic inspections to be made of manufacturers, distributors or retailers of the new appliances described in Section 1601 of these regulations, including appliances that have been or are to be installed by contractors or builders at building sites, in order to determine their compliance with this Article.

(c) The test would involve one unit selected by the executive director.

(1) If the performance of the appliance falls within the tolerances listed below, no further action is necessary, and the Commission will pay the cost of testing.

Appliance	Characteristic	Tolerance Limits (percent of certified value)
Plumbing fittings	Water flow rate	Not more than 110 percent

* * * * *

(2) If the performance of the appliance does not fall within the tolerances listed above, the manufacturer must pay the cost of testing and take whatever steps are necessary either to recertify the appliance at a lower efficiency rating or to provide information to the satisfaction of the executive director that:

(A) in the initial certification of the model, the method of selecting the test sample complied with the requirements of Section 1603 and

(B) in the initial certification of the model, the value certified was in conformance with the requirements of Section 1603.

Even if this information is provided, the manufacturer shall be required to test a second unit, selected by the executive director, in a laboratory acceptable to the executive director, at the manufacturer's expense.

(3) If the performance of that second unit described in subsection (c)(2) falls within the tolerances listed in Subsection (c)(1), no further action will be taken. If the performance of that second unit does not fall within those tolerances, the certification for that model shall be

suspended by Commission order. The manufacturer may retest and recertify the model based on a new sample selected from his current production.

(4) If any of the tests of units required by the executive director pursuant to this subsection are not undertaken by a manufacturer, the certification for that model shall be suspended by Commission order.

1608. Release of Manufacturer Information. (a) Any manufacturer who submits information to an accepted laboratory for the purpose of complying with the intermittent ignition device requirements of this article may designate that such information be kept confidential as within an exception of the California Public Records Act (Sections 6250-6261 of the California Government Code) by so marking such information in a plain and legible manner. Thereafter, the Commission shall not disclose or otherwise make available to the public such information unless the procedures in this section have been followed.

(b) If the Commission or any person desires public disclosure of information designated confidential as presented above, the Commission shall promptly notify, in writing, the affected manufacturer and allow the manufacturer opportunity to demonstrate to the Commission that the requested information falls within an exception of the California Public Records Act (Sections 6250-6261 of the California Government Code), and therefore should not be disclosed. The Commission shall give written notice of its decision to the manufacturer and any other persons requesting notification. Information shall not be publicly disclosed until fifteen days after the Commission decision has been rendered and notice thereof has been received by the manufacturer.

APPENDIX C

FACTORS USED FOR COMPUTING ENERGY SAVINGS[1]

The values and assumptions used in computing the energy savings for the study are contained in this appendix.

Water Heating Energy Savings

Average blended water temperature rise (Used in Department of Water Resources Bulletin 198, May, 1976, calculations; conservative compared to Sacramento tests and 52° rise assumed in model by L.K. Baker et al in Household Water Conservation Effects on Water, Energy, and Wastewater Management, Water Use Conference, May 4-8, 1975 (Chicago)	42°F
Electric water heater efficiency (American Gas Association, Science Application, Inc., tests)	90%
Gas water heater efficiency (same source)	65%
Water heater by type (average) (Southern Cal Edison, Southern Cal Gas, San Diego Gas & Electric, Pacific Gas and Electric)	90% gas 10% electric
1 BTU (gas) equivalent to 1 BTU refined oil.	
1 BTU (electric) equivalent to 2.89 BTU (refined oil) (Above two values from Energy Requirements of Alternatives in Water Supply, Use, and Conservation: A Preliminary Report, by E.B. Roberts and R.M. Hagan, Appendix A-3, December 1975.)	

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[1] From an unpublished memorandum by J. Koyasako and D. Engdahl, California Department of Water Resources, June 1976.

Average energy content of oil (Federal Power Commission, January 1976)	1.44×10^5 BTU/gal
1 bbl oil	42 gal
1 BTU	1°F Delta T/lb water
1 gallon water	8.34 lb.

Gas saved would replace oil in power plant electrical generation.

Electricity saved would have been generated by oil burning.

Oil is taken as power plant-ready refined.

Energy Saved in Gas Water Heaters

$$= (.90 \text{ fraction heaters gas})\ (3.26 \times 10^5 \text{ gal/ac-ft})\ (8.34 \text{ lbs/gal})\ (42^\circ \text{ Delta T})\ (1/0.65 \text{ heater efficiency})\ (\text{BTU/lb}^\circ\text{F Delta T})$$

$$= (.90)\ (3.26)\ (8.34)\ (1/.65)\ (42)\ (10^5) \text{ BTU/ac-ft}$$

$$= 1.58 \times 10^8 \text{ BTU/ac-ft}$$

Gas Saving Conversion to Oil

$$= \frac{(\text{BTU oil})\ (1.58 \times 10^8 \text{ BTU gas/ac-ft})}{(\text{BTU gas})\ (1.44 \times 10^5 \text{ BTU oil/gal})\ (42 \text{ gal/bbl})}$$

$$= 26.12 \text{ bbl/ac-ft}$$

Energy Saved in Electric Water Heaters

$$= (0.10 \text{ fraction heaters electric})\ (3.26 \times 10^5 \text{ gal/ac-ft})\ (8.34 \text{ lbs/gal})\ (42^\circ\text{F Delta T})\ (1/.90 \text{ heater effic})\ (\text{BTU/lb}^\circ\text{F Delta T})$$

$$= (0.10)\ (3.26)\ (8.34)\ (1/.90)\ (10^5)\ (42) \text{ BTU}$$

$$= 1.27 \times 10^7 \text{ BTU/ac-ft}$$

Electric Saving Conversion to Oil

$$= \frac{(2.89 \text{ BTU oil})\ (1.27 \times 10^7 \text{ BTU elec/yr/ac-ft})}{(\text{BTU elect})\ (1.44 \times 10^5 \text{ BTU oil/gal})\ (42 \text{ gal/bbl})}$$

$$= 6.07 \text{ bbl/ac-ft}$$

Total Heating Energy Savings (Constant k_1)

$$k_1 = 26.1 + 6.1 = 32.2 \text{ bbl/ac-ft}$$

Local Systems Savings

Pre-treatment Energy Savings

Calculations of savings in energy in pre-treatment of water were based on the East Bay Municipal Utility District model described in *Energy Requirements of Alternatives in Water Supply, Use, and Conservation: A Preliminary Report* by E.B. Roberts and R. M. Hagan, December 1975, at page 40.

Total energy for pre-treatment, including chemical production and transportation and plant operation energy is 37.2 kWh/ac-ft.

Distribution Energy Savings

From the same source, pp. 40-41, the East Bay MUD distribution system energy is given as an average of 203 kWh/ac-ft, and was taken as representative of systems statewide.

Conversion to Oil Savings

1 BTU electric = 2.89 BTU oil
1 kWh = 3.41×10^3 BTU
1 gallon refined oil contains 1.44×10^5 BTU
1 barrel oil = 42 gallons
1 kWh electric = (3.41×10^3 BTU electric) (2.89 BTU oil/BTU electric)
= 9.85×10^3 BTU oil
BTU/bbl = (1.44×10^5 BTU/gal) (42 gal/bbl)
= 6.05×10^6 BTU/bbl

$$\text{bbl/kWh electric} = \frac{9.85 \times 10^3 \text{ BTU oil/kWh electric}}{6.05 \times 10^6 \text{ BTU/bbl}}$$

$$= 1.63 \times 10^{-3} \text{ bbl/kWh}$$

Local Systems Cost Summation (Constant k_2)

The sum of pre-treatment plus local distribution energy costs is:

Pre-treatment	37.2 kWh/ac-ft
Distribution	203.0 kWh/ac-ft
TOTAL	240.2 = 240 KWH/ac-ft

If all savings are in electricity, oil saving

k_2 = (2.40×10^2 kWh/ac-ft) (1.63×10^{-3} bbl/kWh)

= 0.39 bbl/ac-ft